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Section 7 Fish Habitat Monitoring Protocol for the Upper Columbia River Basin

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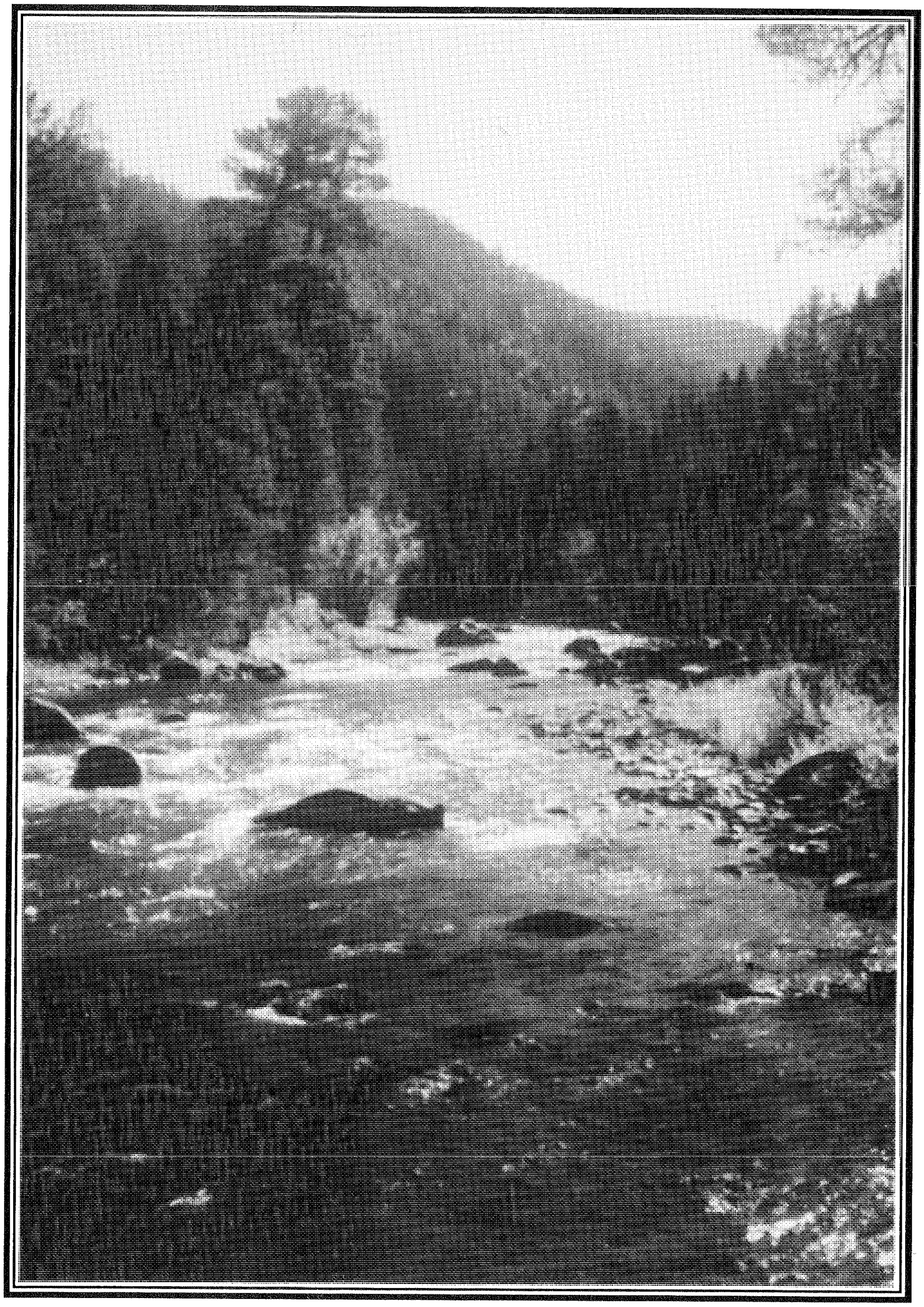

PREFACE

The Columbia River Basin Task Force, an interagency team of research and management scientists chaired by Glenn Chen, is to be complimented for its work on protocols for monitoring fish habitat in the upper Columbia River Basin.

Many opinions exist among biologists and hydrologists as to what parameters and methods should be used when monitoring the effects of land use on fish habitat resources. Reaching a consensus on the protocol to be used throughout the Basin was, and will continue to be, a difficult task. We intend to issue errata to this protocol as new information becomes available and consensus is reached on its application.

I have appended several letters from Glenn Chen which demonstrate the differences in techniques as well as parameters to be monitored.

Gordon Haugen
CRB/Pacfish Field Coordinator

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SECTION 7 FISH HABITAT MONITORING PROTOCOL FOR THE UPPER COLUMBIA RIVER BASIN

Sixth Revision: 6/4/94

INTRODUCTION: PURPOSE AND NEED FOR THIS DOCUMENT

Many stocks of anadromous salmonids in the Pacific Northwest are potential candidates for listing as endangered, threatened, or sensitive (Nehlsen et al 1991). Concern has been focused recently on those species and stocks found in the Columbia River basin. The influence of a broad range of management activities on these fish and their habitat became the subject of an intensive interagency effort to develop strategies to prevent their further decline (FEMAT and PACFISH). It is recognized that much of the remaining habitat available to support these stocks exist on National Forest and Bureau of Land Management lands.

With the special concerns for some threatened, endangered, or sensitive (T/E/S) salmon and steelhead stocks in the upper Columbia River basin, the National Marine Fisheries Service (NMFS) has become involved in the assessment of Forest Service and BLM land management activities. The Forest Service and BLM have entered into special Endangered Species Act Section 7 consultation for evaluating whether or not their land management activities have the potential to affect salmonids and fish habitat in upper Columbia River streams. Several recent activities proposed for the upper Grande Ronde River in northeastern Oregon and other watersheds in Idaho and Washington have prompted NMFS to mandate that the Forest Service and BLM re-develop and upgrade the monitoring proposed for assessing land use effects.

The Columbia River Basin Task Force convened an interagency team of research and management scientists to draft a monitoring protocol for the NFMS Section 7 requirements. The team worked on this project during October - April of 1993-1994 to develop and revise the protocol. Members consisted of the following persons:

Deborah Konnoff, USDA Forest Service, Region 6 Fish Habitat Relationships Coordinator
Gordon Reeves, USDA Forest Service PNW Research Station Corvallis,
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Steve Kozel, USDA Forest Service, Boise National Forest
Jill Dofour, USDA Forest Service, Sawtooth National Recreation Area
Julie Perrochet, USDA Forest Service, Klamath National Forest

TYPES OF MONITORING TO BE CONDUCTED

Three categories of monitoring are recognized by regulatory and land management agencies:

1) *Implementation Monitoring* to determine if standards and guidelines/best management practices were applied to management activities;

2) *Effectiveness Monitoring* to determine if standards and guidelines/best management practices were effective in achieving their objectives; and

3) *Validation Monitoring* to determine if assumptions, coefficients, models, etc... used in activity planning were valid.

The protocol for monitoring of Section 7 upper Columbia River basin salmonid habitat focuses on **implementation** and **effectiveness** monitoring. Validation monitoring is being addressed in the research efforts of USDA Pacific Northwest Forest and Range Experiment Station watershed/fisheries scientists. This division of responsibilities is based upon the different roles and functions of NFS managers and USFS/PNW research in developing protocols for upper Columbia River Basin/Section 7 monitoring.

While we recognize that monitoring is a critical element in our management of natural resources, we often do not succeed in our efforts because we fail to develop clear and focused objectives; because the study design employed was not concise, logical, and methods were not quantitative; and because natural variability in the systems is poorly understood and not adequately accounted for (Azuma and Mori, 1990).

IMPLEMENTATION MONITORING

This type of monitoring is intended to verify that appropriate resource protection standards and guidelines (S&G's) and/or best management practices (BMP's) were employed during the implementation of the management activity. It does not actually assess whether or not the S&G's/BMP's were effective in meeting desired protection goals.

Implementation monitoring can be performed through documentation of the resource protection measures that were employed during project implementation. The S&G's and BMP's applicable to the activity are usually specified in the project planning documents.

Implementation monitoring is usually the responsibility of agency personnel who are involved in contract administration, inspection or supervision of the project. A checklist can be used as a simple means of documentation. For Section 7 upper Columbia River Basin salmonid monitoring, the following list of questions were derived from the USFS Region 6 Water Quality Best Management Practices (BMP) Standards. This is a suggested list and should be modified (including additions or deletions) based on the activities and issues relevant to a particular management area:

Implementation Monitoring Checklist

OVERALL AQUATIC RESOURCE PROTECTION GOALS

Were Desired Future Conditions (DFC's) described?..Y/N
Were actions in the Biological Assessment designed to meet DFC's?..........................Y/N

TIMBER MANAGEMENT

Were Unstable Lands identified and appropriate management prescriptions applied?.......Y/N
Were Streamside Management Units and Wetlands Designated and appropriate management prescriptions applied?...Y/N
Were areas disturbed by harvest activities re-vegetated?...Y/N
Were Erosion Control measures implemented on Skid Trails?.................................Y/N
Were Erosion Control Structures installed and Maintained?....................................Y/N

ROAD SYSTEMS

Was an Erosion Control Plan implemented?...Y/N
Were Bridge and Culvert Installed as planned?...Y/N
Was a Road Maintenance plan developed and implemented?...................................Y/N
Were Obliteration of Temporary Roads and Landings completed as planned?................Y/N

WATERSHED MANAGEMENT

Were Wetlands Identified and Protected?..Y/N
Were waters influenced by Activities Under Special Use Permits identified and protected?..Y/N

MINING

Were Water Resources identified and Protected on Locatable Mineral Operations?.........Y/N
Were Terms of SLM Issued Permits or Leases for Mineral Exploration and Extraction of National Forest System Land Implemented?...Y/N

RECREATION

Were activities of Off-Road Vehicle (ORV) Use managed to prevent adverse effects on water quality?..Y/N
Was Water Quality protected within Developed and Dispersed Recreation Areas?..........Y/N

RANGE MANAGEMENT

Were Range Analyses, Allotment Management Plans, Grazing Permit System, and Permittee Operating Plans implemented?..Y/N
Were Livestock Numbers and Season of Use controlled?..Y/N
Was Livestock Distribution within Allotments controlled?.......................................Y/N
Were Rangeland Improvements implemented as planned?.......................................Y/N

EFFECTIVENESS MONITORING

In contrast to implementation monitoring, effectiveness monitoring is intended to evaluate whether or not the standards and guidelines or best management practices employed during project implementation were effective in protecting resources. Effectiveness monitoring forms the majority of the Section 7 protocol that is presented in this document.

The focus of NFMS consultation is on the issue of whether or not land use activities will result in mortality (a "take") of T/E/S upper Columbia River salmonid stocks. Unlike such activities as commercial fishing or hydropower generation, Forest Service and BLM land management activities generally do not result in direct "take" of fish. Land uses such as timber harvest, roading, or grazing largely affect habitat and water quality and thus effectiveness monitoring of management activities is focused on the protection of habitat parameters as surrogates for "take".

Interim selection of surrogate habitat parameters for Section 7 Effectiveness Monitoring

The interagency team selected a core set of monitoring parameters from the desired future habitat condition list produced in the earlier PACFISH/FEMAT efforts (Appendix 5K, FEMAT PACFISH Goals and Objectives and SAT Report). These parameters constitute the suggested elements to be monitored in the Section 7 protocol and are as follows:

INTERIM SALMONID HABITAT PARAMETERS FOR SECTION 7 MONITORING

1. Pool Frequency
2. Large Woody Debris
3. Width:Depth Ratio
4. Stream Water Temperature
5. Bank Stability
6. Lower Bank Angle

These surrogate elements are diagnostic of overall habitat conditions and will be applied based on their suitability to assess particular effects for specific locations and situations.

The PACFISH/FEMAT parameters are currently undergoing additional scientific review to re-evaluate their utility as key indicators for land use effects. This list should therefore be considered as an *interim* set of monitoring parameters that may be modified with additional data and information collected in the upper Columbia River basin.

Unifying principles of this monitoring protocol: the basin inventory

The common denominator throughout this protocol is the basin-wide habitat/channel morphology inventory and its use to locate and stratify monitoring sites to deal with sources of variability. Basin-level approaches are crucial for avoiding statistical bias in monitoring commonly associated with selecting so-called "representative" reach segments. Quantification, accuracy, repeatability, and the ability to address spatial and temporal variability are requisites for monitoring parameters. These are fundamental requirements used for collecting data in the basin-wide survey methodology.

Successful monitoring is both effective and efficient. With the exception of stream temperature, each monitoring method is based on a survey technique used in basin inventories and can therefore be easily-integrated into a cohesive approach, where all six elements can be assessed simultaneously. Although there may be different and "better" ways to monitor each of the elements, using a combination of widely-different methods to select sites and sample the data often proves to be costly and time-consuming. Monitoring then becomes difficult to support and is often discontinued.

The methods for each DFC parameter require that some sort of initial inventory be conducted. A basin-wide survey which covers elements of each method is an efficient means of obtaining such information. For use in this monitoring protocol, the inventory should assess *reach type* (either by using Rosgen-type classifications or actual measurements of channel width : valley floor width); classification of the channel into *geomorphic habitat units*; *channel and habitat unit dimensions* including width, maximum depth; and *channel gradient*.

Types of impacts to be assessed in effectiveness monitoring

In the following pages of this document, the monitored protocols that will be presented distinguish between direct and indirect or cumulative effects. Definitions of these are as follows:

Direct Effects: Effects on aquatic resources which occur as a direct result of an activity

Indirect and Cumulative Effects: Effects on aquatic resources resulting from multiple past, present, and proposed future activities occurring throughout a watershed basin (cumulative) OR effects from activities originating off-site which may indirectly affect aquatic resources.

Examples of each are:

DIRECT EFFECTS: Harvest of trees in a riparian area, which removes shade canopies and exposes the stream to direct solar radiation, causing an increase in stream water temperatures

INDIRECT EFFECTS: A streamside shade canopy buffer, left after timber harvest, that falls down during a windstorm because of timber harvest activities around it which change stand susceptibility to blowdown; the loss of shade caused indirectly by upslope harvest activities result in increased stream water temperatures.

CUMULATIVE EFFECTS: All land use activities which have occurred, continue to occur, and which are likely to occur in a watershed that increase stream temperature through a multiple combination of direct and indirect mechanisms.

General descriptions of study designs to monitor particular land use impacts

Two approaches are commonly used to monitor direct or indirect/cumulative land management activity effects. These are summarized below:

Direct Effects: Paired sampling site designs are usually employed for assessing direct land use effects. The monitoring sites are located upstream ("control") and downstream ("treatment") of the activity. The control site represents conditions where the monitoring parameter(s) of interest is (are) not affected by the management activity. The focus is on monitoring effects within a limited spatial and temporal framework.

Indirect and cumulative effects: The study design usually employed for monitoring indirect/cumulative effects is the grouped watershed approach, where data from a set of non- or relatively unmanaged "control" watersheds are compared to those being managed ("treatment" watersheds). Physical features of both control and managed watersheds are otherwise as similar as possible (basin size, geology, climate, etc...). This is often done by selecting groups from within a watershed (eg, comparing tributaries) or within an "eco-region" (comparing watersheds based on physiographic similarities). An additional and important requisite for choosing control watersheds is that they must have similar potential for response to land uses (Platts et al 1987). Using more than a single control watershed also increases sample size and degrees of freedom which is necessary for statistical purposes. The focus of indirect/cumulative effects monitoring is on assessing land use effects over broad spatial and temporal scales.

SHORT-TERM VERSUS LONG-TERM MONITORING AND LEVEL OF RESOLUTION

A concern raised by both resource specialists and agency decision -makers is that the habitat parameters selected here will not be useful for evaluating short-term results of S&G or BMP implementation. This is due to the fact that the biological and physical processes which affect the DFC elements operate on long time scales. For example, significant lags exist between recovery of riparian vegetation from harvest and subsequent input of large wood to the stream. Such concerns are understandable; while we desire to obtain accurate results from our monitoring programs with a minimal time and dollar investment, detecting the response of these fish habitat DFC elements to land management activities may take periods of years or decades. **Adequate monitoring of these habitat parameters will thus require long-term commitments by our agencies.** The bottom line is that monitoring must be carried out at this level to yield the resolution capable of addressing our fish habitat protection/land use issues. Aquatic resource specialists should be supported financially and administratively in their efforts to conduct such long-term monitoring.

Qualitative methods do exist which provide some clues as to the effectiveness of BMP's/S&G's within a relatively short time period. Some of these are presented in this document (see Appendix A, Photo Points, and Appendix B, Vegetation Surveys). However, it is important to consider the level of resolution that is provided by such methods. The data is difficult to analyze because it is primarily non-quantitative and parametric statistics cannot be used because nearly all assumptions and requirements are violated. Assessments of effectiveness are difficult because sources of temporal and spatial variability are not adequately accounted for in the sampling design; consequently, natural variability cannot be isolated from management effects. This leads to a wide variety of possible data interpretations. Nearly all such "short-term" methods suffer from these drawbacks. Their limitations are often not recognized and they are commonly used inappropriately . Simplicity is a major attraction, but their level of resolution is usually inadequate to address the T/E/S salmonid habitat protection issues in the upper Columbia River basin..

HOW THIS DOCUMENT IS ORGANIZED

On the following pages, specific methods for effectiveness monitoring of the six DFC parameters is presented. Each section provides a Desired Future Condition description, including suggested threshold values derived from available upper Columbia River Basin data; a description of the specific monitoring objective and data of interest; presents a literature overview of the element's biological and physical importance, and relationship to land management activities; discusses how spatial and temporal variability and observer bias

affects its measurement, analysis, and interpretation; outlines sampling design strategies based upon statistical considerations to reduce sources of variability; the specific type of effect which the parameter can address (*indirect/cumulative* versus *direct* effects); and discusses data calculation, analysis, and interpretation of results. **A summary table** (TABLE A) of DFC elements, monitoring objective, sampling strategy, is provided on page 9.

The threshold values for DFCs are to be considered as interim

While threshold values are given for some of the DFC elements and are based on the PACFISH guidelines and regional scientific data, it is strongly suggested that these values should actually be derived from local groups of watersheds representing "natural" or low-management disturbance conditions. Utilization of such site-specific data provides a more accurate means of interpreting the fish habitat DFC monitoring data, and assessing land use effects.

Relationship of this monitoring document to other protocols: re-inventing the wheel?

One reviewer pointed out that this document did not appear to be integrated with other published monitoring manuals and that it could be perceived as a "re-inventing the wheel" duplication effort. In fact, much of the conceptual framework, specific methods, etc... were borrowed from the many authors listed in the citation section. Manuals such as Platts et al (1987) and MacDonald et al (1991) provided us with an excellent review of many aquatic monitoring methodologies and strategies. The concept of dealing with sources of variation, which is a key theme in this document, is heavily emphasized in both Platts et al. and MacDonald et al.

A common complaint among aquatic resource specialists is that many monitoring publications tend to be generalized or conceptual in nature. We have attempted to provide very specific guidelines on identifying a key set of parameters sensitive to specific land use activities taking place in the upper Columbia River Basin; measuring these parameters; reducing spatial/temporal/observer variability; designing a monitoring study; selecting the appropriate sample sites; identifying the necessary sample size; and how to interpret and analyze the data via parametric, non-parametric, or qualitative methods. This will hopefully fill the gap between the concepts presented in most monitoring manuals and their actual implementation.

Table A. Summary of Fish Habitat Effectiveness Monitoring Parameters and Methods

DFC Parameter	DFC Objective Description	Derived CRB value	Sampling scheme	Type of land use & Direct effects or indirect/cumulative?
Pool Frequency	Frequency of 3'+ deep pools in C-type low-gradient channels	1/6 chan widths	All pools in all C-type reaches	Indirect/cum Harv/Rd/Graze
Large Woody Debris	East: Frequency of 20" diam & 30' long LWD in bankfull channel	20 pc/mi	Entire channel w/ fish	Indirect/cum Harv/Rd/Graze
	West: Frequency of 36" diam & 50' long LWD in bankfull channel		80 pc/mi "	"
Width: Depth	Mean wetted width:max pool depth ratio in C-type channels	10	Upstr/downstr All pools in C-type reaches	Direct Graze Indirect/cum Harv/Rd/Graze
Water Temperature	July-Aug maximum average temperature	68 °F	Upstream/ downstream sites	Direct Harv/ Rd/Graze
Bank Stability &	% unstable bank	?	Upstream/ downstream sites	Direct Graze
Bank Angle	Maximum lower bank angle	< 90°		

HABITAT ELEMENT: CHANNEL MORPHOLOGY -- POOL FREQUENCY

DESIRED FUTURE CONDITION

Inherent (historic) channel-forming/maintenance processes continue to operate without substantial long-term, watershed-wide modifications. Relatively large and deep pools, persistent during the lowest flows, are frequent and well-distributed. These pools provide a variety of functions for maintaining the general health of stream ecosystems. The frequency of pools occurring in low-gradient, unconstrained valley floor reaches (C type channels; Rosgen, 1985) are of special concern since such sites are important for fish diversity and production and are also most sensitive to land use activities that affect the number, distribution, and characteristics of pools.

Sedell et al (unpublished data) determined that pools greater than 3 feet in depth are critical for optimum survival of anadromous salmonids in 3rd to 5th order Columbia River basin streams east and west of the Cascade Mountains, and suggest that these *pools should occur at a frequency that exceeds 1 per 6 channel widths.*

POOL FREQUENCY MONITORING OBJECTIVE

Monitor the effects of land management activities on **the frequency of pools greater than 3 feet in residual depth** at base flow in unconstrained C-type channels, for streams in the upper Columbia River basin. Determine if the standards and guidelines or best management practices employed in timber harvest/roading or grazing activities are effective in maintaining or increasing the frequency of deep pools in the stream channel.

JUSTIFICATION FOR MONITORING POOL FREQUENCY

Biological importance

Pools provide important habitat throughout all salmonid life stages (Bjornn and Reiser, 1991; Meehan 1991). Pools are critical for adult fish resting habitat; as juvenile and sub-adult rearing habitat for various species; as optimal spawning and inter-gravel rearing locations; and as refuge habitat from drought, cold winter temperatures, and high flows. Pools slow

the transport of nutrients and store them to foster food production within them and in adjacent riffles. Pools serve as sediment storage sites which help to buffer the deleterious effects of sediment pulses on stream biota during high discharge. Pool tails provide optimal spawning areas for salmonids due to hydraulic gravel sorting and intergravel flow characteristics.

Physical importance

Pools are persistent features of streams channels and are considered to be locations of sediment transport in the channel (Knighton 1987). They are easily identified by visual characteristics and various channel classification schemes have been developed which define pools as unique units (e.g., Bisson et al 1982; Hawkins et al 1993). The presence and abundance of pools is an important indicator of channel unit physical diversity (Sullivan et al 1987). However, Peterson et al (1992) suggest that primary pools (Keller and Melhorn 1973) may actually be relatively insensitive to management activity effects. Pool characteristics for monitoring should be selected which will show some response to land use impacts.

Relationship to management activities

Forest and range management can alter channel morphology by changing the amount of sediment, water, and large woody debris (LWD) contributed to streams. These can in turn affect the formation and maintenance of pools and thus influence their frequency in the stream. While pools tend to be stable channel features that persist through annual high flow events, their size and location may change if sediment loads increase due to roading, timber harvest, or grazing activities. Excess aggradation caused by large amounts of sediment can smooth the channel by filling pools. The removal or reduction of woody debris reduces sediment storage and eliminates the local hydraulic variability that influences pool development (Sullivan et al 1987). Reduced frequency, depth, and volume of pools, fewer and smaller sizes of in-channel wood debris, and a higher proportion of riffles and shallow pools are expected in intensely-managed watersheds. Numerous studies have described these conditions in association with timber harvest (e.g., Beschta and Platts, 1986; Bilby 1984; Bisson and Sedell, 1984; Clifton 1989; Lisle 1981, 1982; Megahan et al 1980; Murphy et al 1986; Robinson and Beschta, 1990; Sullivan et al 1987).

A variety of human activities, including timber harvest, instream debris removal, mining, log rafting, water impoundment, livestock grazing, roading, and water withdrawal have changed the complexity of Pacific Northwest stream channels over the last 50 years (Sedell and Froggatt, 1984). Preliminary results in comparing historical pool data for Idaho streams with 1990-92 survey data indicate that non-wilderness streams with land use (timber harvest, grazing, etc...) activities have lost up to 50% of the large pools found 5 decades ago; wilderness streams exhibited smaller changes in pool frequency during this same time period

(R. Thurow, personal communication). Similar observations have been noted in other Columbia River tributary watersheds (Sedell et al, unpublished data). In western Washington streams, post-timber harvest debris cleaning of streams was suggested as the mechanism for the reduced pool frequencies observed in stream along clearcut units (Bisson and Sedell, 1984).

METHODS FOR DETERMINING POOL FREQUENCY

The data of interest in this monitoring objective is the **frequency** (per mile) **of pools greater than 3 feet in residual depth** at base flow in streams of the upper Columbia River basin.

This section will discuss how a pool is defined according to bed topography and surface flow characteristics; the rationale behind selecting a 3-feet depth to characterize a deep pool; how temporal and spatial variability influences pool frequency; and how this variability affects sampling methods and monitoring study designs to determine the effect of land management activities on this parameter.

Physical definition of pools

Pools are identified as distinct channel units in the stream by bed elevation and surface flow features. Pools form where scour elements occur in the channel. These elements may include large roughness features adjacent to or within the channel, such as boulders, bedrock steps, bedrock outcrops along the bank, in-channel large wood debris (LWD), or root masses from trees along the bank. Bisson et al (1982) and Hawkins et al (1993) channel classification schemes provide guidelines for identifying pool units.

A pool begins where there is a noticeable change in bed elevation caused by the pool-forming element(s). The head of a pool is defined as the location where the effect of scour creates a change in bed elevation resulting in increased depth. Downstream of the scour, hydraulic forces decline so that deposition occurs, and the bed elevation slopes upward. The pool then enters a shallow, sometimes long, pool tail area with a more gradual bed slope. The pool ends at the pool tail crest, a location which marks a transition in surface flow and the influence of various energy forces, and where the bed elevation is greatest (eg, shallowest depth). In a pool, bed elevation changes occur not only in this longitudinal direction, but laterally from bank to bank as well.

Water flow across most of the surface area of pools tends to be tranquil instead of turbulent. There is a typically a transition in flow where the stream channel enters the pool at its head (turbulent surface to tranquil) and where it exits at the pool tail crest (tranquil to turbulent). These transitions are visually discernible as ripples, whitewater or other forms of surface

disturbance and are known as hydraulic jumps. While exceptions may be quite common (eg, overall surface turbulence will be greater for pools located in higher gradient stream reaches), turbulence does not dominate the entire surface of the pool during base flow conditions.

Standardization of pool size criteria is suggested for maintaining consistency in their monitoring. A pool must extend laterally from bank to bank to be counted. This is a generally-accepted criteria in a number of methodologies (eg, USFS R6 Riparian Inventory). Small, localized areas of bed scour may occur in cascades or rapids and appear to be pools, but these sub-units should not be counted as individual pools for monitoring purposes.

Changes in elevation should be used to locate the head of a pool. Bed topography rather than surface flow changes should be used to identify the pool head, since the flow transition does not always correspond to the precise area of elevation change. Both changes in bed elevation and surface flow should be used to locate the end of a pool.

Pool tail areas can be extremely long and homogeneous, and some stream surveyors break them out separately as glides. Hydraulically and geomorphically, the long, shallow, and evenly-flowing tail sections are still part of the pool above and should not be considered as a different channel unit.

Several reviewers expressed their concern about these dimensional/morphology criteria for pools. Habitat types such as pocket pools, localized lateral scour pools along banks, etc... were felt to be important as "pool" habitat, but would not be included if the above guidelines were used. Azuma and Fuller (in press) and others have suggested that the high degree of complexity inherent in natural channels significantly affects the ability of observers to classify habitat types and assess their dimensions. Classification schemes which break down pool types into a variety of sub-habitats are subject to variability due to observer experience and the gradation (rather than the clear distinction) of identifying features commonly found in streams. Different habitat units can be found side-by-side and difficulty arises when one attempts to determine which type(s) is(are) dominant. While sub-classification of smaller, distinct units laterally or longitudinally within the basic pool/riffle types may be extremely useful for inventory purposes, or for assessing microhabitat use by various fish species/age classes, it creates an unacceptable level of variability for monitoring and affects the repeatability of these measurements. The guidelines specified in this section are designed to minimize such sources of error.

Definition of a deep pool for pool frequency monitoring

Pool depth appears to be one of the principal factors influencing the diversity and abundance of salmonid fish in streams. Chen (unpublished data) noted that significant differences in juvenile salmonid community diversity existed between pools less than or greater than 1

meter in residual depth (Oregon coastal streams). Sedell et al (unpublished) reviewed data obtained from Oregon, Washington, and Alaskan streams, including a number of upper Columbia River basin streams, and found that pools greater than 1 meter in depth supported higher numbers and diversity of salmonids. Research by Nielsen et al (in press) documents the importance of deep pools as thermal refuges by salmonids during drought. These sources of information was used to derive the **3 feet minimum** criteria for a deep pool.

Temporal variation in discharge and how it affects the frequency of pools and their monitoring

Pools are an easily-recognized morphological feature of natural stream channels during base flow periods. The dimensions of pools, however, vary with changes in flow. Level of stream discharge will affect all pool measurements, and methods for quantifying pool size and frequency must take into account this source of variation.

Stream discharge fluctuates in time with changes in net precipitation or snowmelt in a watershed. These inputs can vary hourly, monthly, and seasonally. The changes in discharge and water level affect all features of pools, including surface area, depth, and volume. High flows can re-sculpt stream channels, changing channel units and their location and distribution. During runoff events, a riffle-pool section may appear to become a long rapid, with pools no longer definable as distinct units. Such variation occurs seasonally with timing dependent upon the dominant form of precipitation (rain versus snowmelt). Stage of flow is thus an important factor to consider when monitoring pools in stream channels.

Residual pool depth to account for temporal variability in discharge

Lisle (1987) developed the definition of **residual pool depth** which allows the standardization of pool dimensions independent of discharge. Determination of residual depth requires a measurement of maximum pool depth and the pool tail crest depth. The pool thalweg (defined as the longitudinal axis that follows the deepest contour of the pool) is first located. Surface-to-bottom depth measurements are taken along the thalweg with a graduated rod and the greatest depth is recorded as the *maximum depth*. The *pool tail crest depth* is determined by locating the tail crest (identified as the deepest point in the pool tail which corresponds to the location of the hydraulic jump) and then measuring the surface-to-bottom depth at this point. Measurements should be made to the nearest 10th of a foot.

To calculate the *residual depth* for a pool, the pool tail crest depth is subtracted from the maximum depth. The residual depth represents the hypothetical depth of the pool if flow was reduced so that the stream became a series of standing, non-connected pools. Because of the importance of minimizing variance due to changes in discharge, the residual depth method should always be utilized when monitoring the frequency of deep pools.

Recent studies by Azuma and Fuller (personal communication) suggest that use of residual depth may not be entirely free of sampling errors. Consistency varied from excellent to variable with statistically-significant "differences" due to observer bias. Reaching a consensus between data collection crews on sampling methods and documentation is critical for maintaining repeatability of pool monitoring.

Spatial variation in pool distribution and how it affects the selection of monitoring sites and the sampling of pool frequencies

Pools are not distributed uniformly in the stream channel. The location of a pool depends on the proximity of pool-forming elements, which are themselves highly variable in space. The distribution of these elements is influenced by many factors and processes, such as stream power and basin size; channel constraint, channel width, and channel gradient; sediment transport and particle size; geology; riparian vegetation; and inputs from hillslope mass movement. Stream power acts in concert with valley morphology to determine the role and distribution of pool-forming elements, and thus affects the frequency and characteristics of pools. This influences the selection of potential monitoring sites, sampling strategies, and the interpretation of the data that is collected.

For example, a stream in a constrained gorge (eg, channel type A; Rosgen, 1985) is usually characterized by a high gradient channel lined with bedrock and large boulders. Such a reach is dominated by frequent, deep plunge pools. In contrast, a stream channel in a wide valley floor is typically low-gradient and alluviated (C type channel). Here, pool formation relies on the presence of streambank vegetation, large log jams, upslope delivery of wood and boulders, or the activities of organisms (eg, beavers and dams). There may be fewer and shallower pools depending on the abundance of these pool-forming elements. Comparing frequencies between sections of a stream may serve only to illustrate intrinsic reach differences and not the effects of land management activities.

A statistically-correct sampling design is critical for any inventory or monitoring procedure. Because pools are not distributed uniformly in stream channels, random or systematic sub-sampling may not adequately account for such spatial variability and lead to sampling errors. These then affect the validity of the analyses. The spatial scale and frequency employed in pool frequency sampling must consider these statistical needs.

A sampling methodology to account for spatial variability and to minimize statistical errors

Random or systematic sub-sampling of channel units in a stream will not account for the highly variable nature of their distributions. Previous types of stream surveys which focused on short "representative" reaches were recognized as biased by statisticians and fisheries scientists. This led to the development of large-scale, whole watershed inventory methods in which complete sampling of habitat occurs. The most widely-recognized methodology was

developed by Hankin and Reeves (1989) and is known as the "basin-wide inventory" procedure. Key elements from the Hankin and Reeves method that can be applied to the monitoring of pool frequency include: 1) Channel unit classification criteria to identify pool units based on Bisson et al (1982); 2) *complete sampling (not random or systematic sub-sampling) of all pool units;* 3) quantification of dimension parameters (maximum and pool tail crest depth for residual depth) for every pool unit.

Criteria for selecting monitoring locations to minimize spatial variation

The morphology of a stream affects the response of pools to the impacts of land management activities. A constrained reach (eg, Rosgen A channel) more readily transports sediment and pools found in such a reach are resistant to change. A low-gradient, wide valley floor reach (Rosgen C type) tends to store sediment and its pools are more easily affected by increases in bedload and discharge resulting from logging, roading, or grazing activities. Thus, to most effectively document changes in pool frequency, monitoring should focus on the low-gradient C-type reaches found in the watershed. For standardization purposes, *low gradient* is defined as having an average channel gradient equal to or less than *1%* (as measured using a clinometer or survey rod and engineer's level).

Reaches chosen for use as pool frequency monitoring sites should be stratified based not only on valley/channel morphology, but on additional channel characteristics that utilize assessments of sediment transport capabilities. Buffington and Montgomery's paper (1993) describe some of the pertinent methods. To account for variation related to stream power and watershed size, streams selected for monitoring should be relatively similar in basin size and channel gradient. These factors influence power and the formation and abundance of pools. All of this data can be obtained in the preliminary basin-wide inventory.

Monitoring land management effects on pool frequency: direct or indirect/cumulative effects?

Land management effects on aquatic resources can be either direct or indirect and off-site/cumulative. The introductory section to this document provides definitions of direct and cumulative effects. Which type of effect is most appropriately addressed by monitoring changes in pool frequencies?

Direct effects are usually assessed by sampling at upstream/downstream sites adjacent to the activity. It may be difficult, however, to ascertain whether or not changes in pool frequencies are due to local, direct effects, or are a result of combined activities originating throughout the watershed. A road failure dumping sediment into a stream, or slumping banks caused by cattle trampling, may be filling in pools adjacent to these sources and appear to be causing direct effects. The source of impacts, however, may also include a number of additional inputs located above the activity site. Transport by the stream channel makes it difficult to isolate land management impacts that affect pool frequency, unless intensive

analyses are performed quantifying sediment/water input, transport, routing, or sediment budgeting. The interaction of multiple activities, sources, and natural processes complicate the evaluation of local effects; the monitoring data collected is thus subject to a variety of interpretations.

Cumulative effects analyses are conducted at large spatial scales of entire basins and are intended to ascertain combined effects of multiple activities. Because of the spatial variability in pool distribution associated with scale, and the additional difficulty in isolating direct effects, pool frequency changes may be more useful for monitoring indirect and cumulative watershed effects. As indicated in the introductory sections, the study design for assessing such effects is the grouped control/treatment watershed comparison.

Monitoring study design to assess indirect/cumulative land management effects on pool frequency

Prior to setting up a pool frequency monitoring program for the group of watersheds, the preliminary inventory data should be analyzed. It is used to locate the low-gradient, wide valley floor reaches (C-type channels) for monitoring sites.

For monitoring, a quantitative survey of *all pool units* located in low-gradient C-type reaches within both control and managed watersheds should be conducted to determine their pool frequencies. All pools should be identified and the residual depth should be determined for each. Sampling should occur during base flow periods, since pools are more easily identified when discharge is reduced.

Pools which are greater than 1 meter in residual depth within each monitoring reach should be tallied. Total miles of each survey reach should be quantified and divided by the number of deep pools to yield a pool frequency per mile for each watershed.

Pool frequency counts should be continue for a period which corresponds to the periodicity of channel-forming flows, input of sediment from land use activities, stabilization of water or sediment input rates and sources affected by land use, and other factors related to the channels' capacity to recover from impacts. It is difficult to pinpoint a specific time duration for pool frequency monitoring because of the influence of unpredictable variables (eg, weather and precipitation), the complex interactions between natural processes and land use effects, and our subsequent inability to accurately predict rates of recovery. Long-term studies of pool recovery following impacts by land uses indicate that time periods on the order of decades may be involved (eg, Megahan et al 1980).

DATA ANALYSIS

Use of parametric statistics requires randomization in sampling and adequate sample size. Assumptions are that the distribution of data is normal and homogenous; that the observations are independent; the variances of the data sets being compared are equal or are of a known ratio; that the data have error variation independent of the means and that the variance components are additive (Ponce, 1980; Devore and Peck, 1986). The data collected in monitoring studies rarely satisfy all of these assumptions and requirements. While this is an important concern in parametric analyses, Glass et al (1972) suggest that a more relevant concern would be the influence that these violations may have on analysis.

The sampling unit is the reach (not individual pools); the entire population is included if all low-gradient reaches are sampled. Normal distribution and homogeneity of variances should be checked before attempting to use parametric statistics (distribution graphing, chi-square goodness of fit, Kolmogorov-Smirnov, or Shapiro-Wilk tests for normality tests; Bartlett's test for variance homogeneity; refer to Ponce 1980, Devore and Peck, 1986). Data can be transformed if not normally-distributed (typically, a log-normal transformation is appropriate; P. Flebbe, USFS SEFES, personal communication). Non-parametric methods are an alternative if assumptions for parametric analysis are not met. There are several ways to analyze the data:

Using an established "natural" range and grouped watersheds

Assuming that requirements for parametric tests are met, the data from grouped control watersheds should be used to calculate a "natural range" (confidence interval or tolerance range) of variability. The managed watershed is then compared to this natural range; if outside the range, this would suggest that indirect/cumulative land uses may be having an effect on pool frequencies. A *t*-test can be used to determine if the differences are significant (the t-test is appropriate for treatment versus control type study, to compare 2 populations when variance is unknown and data are paired or unpaired). The selection of a one-tailed or two-tailed test depends on the null hypothesis (may be appropriate to use 1-tailed since we are interested in determining if the managed watershed mean is less than the control mean pool frequency). The method for the *t*-test is described in Ponce (1980), or in Devore and Peck (1984). Non-parametric statistical tests such as Wilcoxen, Mann-Whitney, or Kruskal-Wallace may be used if parametric assumptions are not met (P. Flebbe, personal communication).

Quantifying % of basin that is managed, determining the amount of sediment input from activities (e.g., sediment modelling or sediment budgets, V* bedload estimation [Lisle 1992], etc...), GIS mapping of activities and affected areas, photographs taken at established points along the channel, and other types of supporting evidence which document that management

has occurred and has generated some effect on pool frequencies should be provided as support for this analysis (P. Flebbe, personal communication). (Refer to Appendix A for description of photo point methodology.)

Using comparisons to the DFC values

If no groups of "control" watersheds are available for comparison, the "natural" range of variability cannot be assessed. The data collected from the monitoring sites should therefore be compared to the interim DFC values listed in Table 1. If the frequencies observed in the managed watershed are less than the table values, this would suggest that management activities may have a cumulative effect on pool frequency.

The analysis should be limited to qualitative interpretation and should be supported with additional data such as that suggested above. It is not recommended that statistical assessments be made on this type of data.

The following table lists recommended pool frequencies developed for various channel widths in Columbia River basin tributaries in the absence of site-specific data collected from comparable "control" watersheds:

Table 1. Pool frequency and channel width relationships.*

For channels with wet width of:	*Desired # pools/mile:*
5 feet	184
10 "	96
15 "	70
20 "	56
25 "	47
50 "	26
75 "	23
100 "	18

*Inventory data from USFS and Bureau of Fisheries surveys in 116 watersheds in Oregon, Washington, Idaho and Alaska were used to develop the above relationship between wetted channel width in streams and the number of channel widths between pools. In these surveys, the criteria used for identifying pools was similar to that discussed in the previous pages (maximum low-flow depth equal to or greater than 1 meter [3 feet]).

The most physically-complex Oregon and Washington streams surveyed in 1988-91 had low pool frequencies compared to the most complex Alaska streams surveyed in 1988-91 and compared to Oregon and Washington streams surveyed in 1938-41. Favorable pool frequency was identified as midway between these two data sets. The formula for deriving these values is:

$$\text{pools/mile} = \frac{5{,}280 \,/\, \text{wetted channel width}}{\text{\# channel widths per pool}}$$

HABITAT ELEMENT: CHANNEL MORPHOLOGY -- LARGE WOODY DEBRIS

DESIRED FUTURE CONDITION

Inherent (historical) channel-forming/maintenance processes continue to operate without substantial long-term or watershed-wide modifications. Frequent and well-distributed complexes of wood debris, comprised of large-diameter pieces greater than the width of the channel, interact with the pools in the channel over time through a wide range of flows to create a diversity of aquatic habitat types.

Sedell et al (unpublished) determined that in-channel pieces of large woody debris should have a frequency equivalent to *one piece per 45 linear feet of channel* for optimum survival of anadromous salmonids in upper Columbia River basin streams. This frequency is currently being re-evaluated with additional regional data and should be considered as interim value.

LARGE WOODY DEBRIS MONITORING OBJECTIVE

Monitor the effects of land management activities on **frequency of large wood debris material** in portions of the basin occupied by anadromous salmonids, in upper Columbia River basin stream channels. Determine if standards and guidelines and/or best management practices employed during timber harvest or roading activities are effective in maintaining or increasing the frequency of LWD in managed watersheds.

JUSTIFICATION FOR MONITORING INSTREAM LARGE WOOD DEBRIS

Biological importance

LWD is one of the most important sources of habitat and cover for fish populations in streams (MacDonald et al 1991). LWD provides suitable habitat over a wide range of flow and climatic conditions. Bisson and Sedell (1984), Sedell (1984a) and Sedell (1984b), Sedell and Swanson (1984), and Bisson et al (1987) found that relationships exist between LWD, habitat complexity, and salmonid production. Chen (unpublished) found that greater complexity of LWD, where it was associated with mean depths greater than 1 meter, were

correlated with juvenile salmonid diversity in southern Oregon coastal streams. Bustard and Narver (1975) documented use of logs, upturned tree roots, and debris accumulations by juvenile coho salmon and steelhead trout as over-wintering refuge habitat. Reeves et al (1993) noted that greater numbers of LWD pieces were found in basins with lower levels of timber harvest and that level of harvest was strongly correlated with salmonid community diversity. LWD also functions as important colonization sites for aquatic macroinvertebrates and their food sources (Harmon et al, 1986; Dudley and Anderson, 1982).

Physical importance

Large wood is a major component of channel form in smaller streams (Bisson et al 1987). LWD can influence channel meandering, bank stability, variability in channel width, increase the average channel width, and affect the form and stability of gravel bars (Lisle 1986). LWD is often the primary physical agent responsible for the formation of pools in small streams. Bilby (1984) reported that 80% of the pools in small southwestern Washington streams were formed by wood, and Rainville et al (1985) found similar associations in small northern Idaho streams. Bisson et al (1987) documented that LWD provided pools and fish habitat along the margins and side channels of larger streams. Megahan (1982) suggested that decreased LWD can result in less sediment storage and increased sediment routing and yield at the mouth of the stream basin.

Relationship to land management activities

Forest and range management can alter channel morphology by changing the amount of sediment, water, and large wood debris contributed to streams, and the capability of the channel to transport and store sediment/water/LWD. The removal of LWD reduces sediment storage and eliminates the local hydraulic variability (Bisson et al 1987). Number, area, and volume of pool decreased as a result of activities which remove of LWD (Bilby 1984).

Streamside logging affects both the amount and size of LWD within streams. Heifetz et al (1986) observed less large organic debris and less pool area in stream reaches bordering harvest unit clearcuts. Ralph (1992) found the size class of woody debris in intensively-logged basins in western Washington to be appreciably smaller than in non-logged watersheds, but the overall number of pieces were not significantly different. LWD was usually smaller and less stable in clearcut-logged stream reaches than in old-growth or buffered areas (Toes and Moore, 1982; Bryant 1983). The number of single pieces of LWD found in harvested Boulder Creek is only half compared to the Rapid River, a non-impacted stream with similar channel types and drainage area (Overton et al 1993).

Bisson and Sedell (1984) found that large, stable organic debris accumulations were lacking from streams in clearcut areas and partly attributed such differences to the widespread practice of debris removal following harvest activities; stream channels in these areas had

increased riffle area and volume and reduced pool frequencies/volume. Similar results and conclusions were noted by House and Boehne (1987). Swanson et al (1984) documented that LWD levels were 3 to 6 times less in clearcut watersheds than in old-growth stands in southeast Alaska.

While LWD in the stream channel can persist for decades, they eventually disappear through time due to natural decomposition, episodic flood events, or removal by human activities. Management of LWD in streams must therefore consider potential sources and delivery mechanisms (Harmon et al 1986).

Sedell and Luchessa (1982) point to the importance of researching the historical record for interpreting LWD data. Extensive and profound changes to LWD in Pacific Northwest streams has occurred due to activities such as removal for navigation purposes; log drives and splash dams; post-harvest stream clean out; etc... (Sedell and Frogatt 1984; Sedell and Duvall 1985; House and Boehne, 1987; and others).

METHODS FOR DETERMINING FREQUENCY OF LWD

The monitoring data of interest is the **frequency of in-channel large pieces of woody debris per mile of stream channel.**

Spatial variability in LWD distribution and how it affects the frequency of LWD and its monitoring

Of all physical elements found in the stream channel, large woody debris has the most variable distribution, influenced by a host of factors related to channel form, valley morphology, and stream discharge. The sources of LWD are affected by the species composition, age class, and stand types found in both riparian and upslope areas; bank and hillslope topography; and the physical processes which deliver wood to the channel. Subsequent transport and storage in the channel is dependent on flow levels, the configuration and size of the wood itself, and location in the channel. Patterns of transport are erratic; LWD accumulations may be stable for years, persisting though many floods, only to wash away and re-assemble during a single high flow event.

Spatial variation in wood distribution also occurs as a result of difference in stream size and power, with smaller, low-power streams usually containing more wood than larger streams. Reach morphology plays a major role in determining LWD distributions, with accumulations more common in unconstrained deposition (eg, C-type channels; Rosgen, 1985) reaches than in constrained gorges (A type channels). However, cross-channel log jams occur frequently in constrained channels and may impede downstream transport of LWD; consequently, LWD loading in the reach downstream may be less than is expected.

The delivery of wood to the channel is itself highly erratic. Episodic events such as large earthflows are thought to deliver the majority of wood material (Bisson et al 1987; Keller and Swanson, 1979), but these occur infrequently and unpredictably. Tree fall from rot or death, on the other hand, deliver smaller amounts of LWD at more frequent intervals.

Sampling methodology to account for spatial variability in LWD and to minimize statistical errors

LWD is not distributed randomly in the stream channel and LWD delivery, accumulation, and transport is not easily predicted. Survey methods to sample LWD must be able to account for its high spatial variability. The distribution of LWD in stream channels is so variable that Overton et al (1993) has found that random or systematic sub-sampling is statistically inadequate for surveying LWD. Overton suggests that complete sampling of an entire stream channel in each basin may be necessary to account for the spatial variability in wood distribution. While wood does tend to occur more frequently in low-gradient, unconstrained C-type channel reaches, the erratic nature of LWD distribution may necessitate large-scale sampling to accurately assess LWD frequencies. Hankin and Reeves (1989) developed basin-wide survey techniques to address the high natural variability of habitat features in streams. The basin-wide survey may be most appropriate for dealing with the spatial variability in LWD.

Since the monitoring objective focuses on the relationship of LWD and anadromous fish habitat, sampling should occur throughout the area of basin occupied by andromous salmonids. This requires prior knowledge of fish distributions obtained through a basin-wide fish population inventory (population sampling portion of Hankin and Reeves, 1989).

Temporal variability in LWD distribution and how its affects the sampling of LWD frequencies

LWD function in the channel varies in time with changing discharge levels. Counting only pieces that are within the wetted channel during low flow surveys may ignore LWD which serve important functions in high flows. Large wood along streambanks, dry during summer flows, become part of the channel during flood events and provide critical refuge habitat refuge for stream biota. Portions of LWD outside the bankfull channel (eg, root masses of downed trees) do not interact directly with the stream but serve to anchor in-channel sections and influence LWD stability. In some cases, logs or whole trees "bridge" the channel; while well above the water during low flow, scour occurs at high discharge as they serve to direct water down towards the streambed.

A sampling methodology to account for temporal variability

LWD monitoring should tally all pieces found not only within the wetted channel, but should include all pieces or accumulations which are wholly within or extend into the bankfull channel. The bankfull channel definition, however, is subject to some ambiguity (Knighton, 1987), especially in areas where the valley is too narrow to develop a floodplain or where several benches exist (Woodyer, 1968).

No consistent method for specifying the bankfull channel exists (Knighton, 1987). Williams (1978) identifies the bankfull channel as the height at which the width:depth ratio becomes a minimum; recurrence interval is also used but Leopold et al (1964) found that the range was very wide ($Q_{1.01}$ to Q_{32}).

In practice, identification of the bankfull channel is commonly based on bank vegetation clues, detritus lines, etc... To minimize observer bias associated with locating the bankfull channel, monitoring crews should visit a stream before the project begins and arrive at a consensus definition of bankfull features. Photo and written documentation should also be collected to ensure consistency in future efforts.

Portions of LWD which extend outside the bankfull width but are attached to the in-channel piece should be included when determining LWD size for frequency tallies.

Variability due to observer bias in LWD surveys and methods to minimize such sources of error

Overton et al (1993) attempted to ascertain the accuracy and repeatability of visual wood debris surveys. They compared LWD estimates collected by a series of seasoned stream surveyors on the same test reach. The data indicated that large discrepancies caused by observer bias were common and that complex categorization schemes only compounded this problem. This source of statistical error was high and affected the subsequent significance tests.

To reduce observer bias, a simplified and unambiguous classification scheme should be used. The minimum LWD length and diameter criteria provide in Table 2 are suggested for use in eastside and westside Columbia River Basin streams if more site-specific data are not available.

Crews should collectively identity and agree upon the length/diameter categories and location of LWD that is to be counted. Decisions should be documented to ensure consistency between different crews and sampling sessions.

Table 2. Minimum length* and diameter for classifying LWD in Columbia River Basin streams[1].**

For streams east of the Cascade Mountains (upper CRB streams):

LWD =	Diameter > 50 cm (20 inches)	
	Length > 10 meters (30 feet)	

For streams west of the Cascade Mountains:

LWD =	Diameter > 90 cm (36 inches)	
	Length > 16 meters (50 feet)	

** measured as greatest length*
***measured at the location of the minimum LWD diameter*

[1]***Interim DFC values to be used if local data on "natural" conditions are unavailable.*** *These numbers were derived from extensive PNW and INT research data collected in Oregon and Washington both within and outside the Columbia River basin and from basin-wide inventory data collected on BLM and USFS watersheds in the CRB (Sedell et al unpublished). It has been suggested by a number of reviewers that these values may be high for some Idaho streams. It will therefore be important to collect LWD data from watersheds with little anthropogenic disturbance so that more site-specific standards can be utilized. An adequate assessment of long-term historical land use activities and large-scale human/natural perturbations (eg, splash-damming, log-driving, snagging, wildfire, floods, etc...) will be critical for selecting representative "natural LWD condition" sites.*

Monitoring land management effects on LWD frequency: direct or indirect/cumulative effects?

Direct land management effects on instream large wood debris may be difficult to separate from indirect or cumulative effects, because, as with pool frequency, transport of material by the channel confuses the patterns of LWD abundance and frequency. LWD can be extremely mobile in the channel and as a result, the wood counted at the sampling sites may or may not be from sources directly affected by the land use activity. Monitoring of LWD frequency may be more appropriate for indirect/cumulative effects analyses. Such analyses take into account a multitude of activities within a watershed that have both off-site and direct effects on LWD sources and input. Overall frequency is assessed rather than local distribution and direct land use effects on patterns of LWD distribution would not have to be isolated.

Monitoring study design to assess indirect/cumulative land management effects on LWD frequencies: control group versus managed watersheds

A basin-wide survey of LWD within the watershed should be conducted in all control and managed streams. All LWD within or extending into the bankfull channel meeting the minimum criteria given in Table 2 (or other established size criteria) should be tallied. Data on log jams should be collected as the number of pieces. All LWD in adjacent side channels that are within the bankfull channel should be included.

Total stream mileage surveyed should be quantified. Total number of LWD pieces should be divided by total survey miles to yield a LWD frequency per mile for the control and managed basins.

The data collected from the control watersheds should be used to develop a "natural" range of variability in LWD frequency. This can take the form of a statistically-derived confidence interval (calculated from the mean frequency and standard error) or a "tolerance range" (D. Turner, personal communication). This range serves as a basis for analysis and interpretation of the monitoring data.

Sampling should be repeated at intervals corresponding to the frequency of LWD input events and rate of vegetation recovery and LWD recruitment as influenced by specific types of land uses. It is difficult to pinpoint a specific time duration for LWD frequency monitoring because of the influence of unpredictable variables (eg, weather and precipitation), the complex interactions between natural processes and land use effects, and our subsequent inability to accurately predict rates of recovery. Research data suggests that time periods for LWD recovery or cycles of input may be in decades or even centuries; and LWD input is highly variable from year to year (Bisson et al 1987). Rather than establish a regular sampling periodicity, intervals for LWD monitoring should be timed to coincide with major natural or anthropogenic disturbance events (large storms, wildfire, major harvest activities, etc...) and continue on a long-term basis. This sampling frequency is probably most effective for monitoring land use effects on LWD.

DATA ANALYSIS

Use of parametric statistics requires randomization in sampling and adequate sample size. Assumptions are that the distribution of data is normal and homogenous; that the observations are independent; the variances of the data sets being compared are equal or are of a known ratio; that the data have error variation independent of the means and that the

variance components are additive (Ponce, 1980; Devore and Peck, 1986). The data collected in monitoring studies rarely satisfy all of these assumptions and requirements. While this is an important concern in parametric analyses, Glass et al (1972) suggest that a more relevant concern would be the influence that these violations may have on analysis interpretations (eg, "Type I" and "Type II" errors).

For LWD frequency, the sampling unit is the basin (not pieces of LWD). However, basins used in either the treatment or control groups were not randomly selected, and while statistics can be used, results cannot be extrapolated beyond the sample (P. Flebbe, personal communication). Normal distribution and homogeneity of variances should be checked before attempting to use parametric statistics (distribution graphing, chi-square goodness of fit, Kolmogorov-Smirnov, or Shapiro-Wilk tests for normality tests; Bartlett's test for variance homogeneity; refer to Ponce 1980, Devore and Peck, 1986). Data can be transformed if not normally-distributed (typically, a log-normal transformation is appropriate; P. Flebbe personal communication). Non-parametric methods are an alternative if assumptions for parametric analysis are not met. There are several ways to analyze the data:

Using an established "natural" range and grouped watersheds

Assuming that requirements for parametric tests are met, the data from treatment watersheds should be compared to the calculated "natural" range (confidence interval or tolerance range) determined from the group control; if outside the range, this would suggest that indirect/cumulative land uses may be having an effect on LWD frequencies. A *t*-test can be used to determine if the differences are significant (the *t*-test is appropriate for treatment versus control type study, to compare 2 populations when variance is unknown and data are paired or unpaired). The selection of a one-tailed or two-tailed test depends on the null hypothesis (may be appropriate to use 1-tailed since we are interested in determining if the mean of the managed watershed LWD frequency is less than the control group). The method for the *t*-test is described in Ponce (1980), or in Devore and Peck (1984).

Non-parametric statistical tests such as Wilcoxen, Mann-Whitney, or Kruskal-Wallace may be used if parametric assumptions are not met (P. Flebbe, personal communication).

Interpretations should be supported by other quantitative data including the % of basin which is roaded or harvested; silvicultural surveys documenting species and age classes of riparian vegetation, or either types of vegetation surveys; mapping of management activities; photographs taken at fixed points in the channel; debris mapping (Platts et al 1987)and other types of supporting evidence which document that management has occurred and has generated some effect on LWD frequencies should be provided as support for this analysis (P. Flebbe, personal communication). (Refer to Appendix A for description of photo point methodology and to Appendix B for plant survey methods.)

The available historical record should be sought out for the monitoring watershed and any information (historical society photographs; aerial photos; anecdotal accounts; agency reports on stream cleaning, debris removal, harvest; or quantitative data) from such sources should be used in LWD data interpretations. This is important for establishing a long-term perspective that would be missing to present-day observers. In many cases, the historical information provides an explanation for otherwise perplexing contradictions between maturity of stands, lack of instream debris, etc...

Analysis without control watershed group data

If a control group is not used, the background range of variability cannot be assessed. The data collected from the managed watersheds should therefore be compared to the LWD frequencies given in Table 3. The analysis should be limited to qualitative interpretation and supported by other data, such as that described above and including the historical record. It is not recommended that statistical assessments be made on this type of data.

Table 3. Frequency of large wood for streams east and west of the Cascade Mountains*

In upper Columbia River Basin streams east of the Cascades range:
Frequency > 20 pieces per mile

In upper Columbia River Basin streams west of the Cascades:
Frequency > 80 pieces per mile

*These values are suggested for use if data from local control watersheds representing "natural" conditions are not available. There were derived by USDA Forest Service Pacific Northwest Forest and Range Experiment Station scientists from their research data in Oregon, Washington, and Idaho..

HABITAT ELEMENT: CHANNEL MORPHOLOGY -- WIDTH : MEAN DEPTH RATIO

DESIRED FUTURE CONDITION

Stream channels should maintain a channel geometry that allows for continued water and sediment transport, at an equilibrium state that results in a relatively stable channel. Under such conditions, channel maintenance processes can continue to create complex habitat for aquatic biota. The width-to-depth ratio is quantitative measure of this channel geometry. Changes in width:depth are of concern in low-gradient, unconstrained reaches (C-type channels; Rosgen, 1985) because such areas are more sensitive to land use effect on channel morphology.

Interim data collected in upper Columbia River Basin streams suggest that a *width:depth of 10* may be indicative of good salmonid habitat conditions and a healthy aquatic ecosystem (Sedell et al unpublished). This value should be modified using more site-specific data from representative "healthy" streams in local areas where monitoring is to occur. Additional information collected from wilderness streams in Alaska show that width:depth ratios of 10 may not occur even in "pristine" systems (K. Overton and B. House personal communication).

WIDTH-TO-DEPTH RATIO MONITORING OBJECTIVE

Determine that standards and guidelines and/or best management practices employed in grazing, timber harvest, or roading activities maintain **the mean wetted width : mean maximum pool depth ratio in managed watersheds** at or below the width:depth values found in "natural" watershed, at low-gradient, unconstrained C-type reaches for upper Columbia River basin streams.

JUSTIFICATION FOR MONITORING WIDTH:DEPTH RATIO

Physical importance

The width:depth ratio provides a dimensionless index of channel morphology. This feature allows comparison between reaches without having to account for differences due to stream

order (Knighton, 1987). The ratio can be used as an indicator of the change in the relative balance between sediment load and sediment transport capacity. Channel morphology is shaped largely through the interactions of sediment and water during channel-forming peak flow periods (Sullivan et al 1987).

Biological importance

An increased width to depth ratio resulting from excessive sediment load, higher peak flows, and accompanying bank erosion can reduce the suitability of stream habitat for salmonids (Platts et al 1987). High and/or increasing width:depth are often linked to reduced channel depth and loss of pool habitat. Widening and shallower channels may increase summer temperatures, decrease winter temperatures, eliminate fish cover, promote ice formation, and reduce invertebrate production (Beschta and Platts, 1986; Beschta et al 1987; Gregory et al 1987; Meehan 1991).

Relationship to land management activity effects

Watershed management activities such as timber harvest, roading, mining, and livestock grazing can affect the quantity and timing of water/sediment delivery to stream channels. Activities that increase the amount of sediment beyond a channel's transport capacity can cause aggradation and loss of depth, widening, and instability as the channel seeks a new equilibrium (Beschta and Platts, 1986; Clifton 1989; Lisle 1981, 1982; Robinson and Beschta, 1990; Sullivan et al 1987; Overton et al 1993). Livestock grazing can cause mechanical shearing of banks and create local changes in width:depth. Both placer and hydraulic streambank mining can alter channel morphology and change the width:depth (Martin and Platts 1981). The width:depth ratio is a sensitive indicator of channel change and has been shown to be useful as a monitoring parameter (Platts et al 1987).

Width:depth ratios are probably more useful in assessing effects in alluvial (eg, Rosgen C-type; 1985) channels than in non-alluvial channels (many A and B-type channels), because bed and banks in non-alluvial channels are typically composed of larger sized, more resistant material, although Lisle (1982) observed bank erosion and channel widening even in non-alluvial channels in response to increased sediment loads.

METHOD FOR DETERMINING WIDTH:DEPTH RATIOS

The monitoring data of interest is the **mean wetted width: mean maximum pool depth ratio.**

Temporal variation in discharge and how it affects width:depth monitoring

The width:depth ratio compares wetted channel width to mean depth. These parameters are influenced by the level of stream discharge, which is highly variable in time. Although the ratio is dimensionless and thus accounts for variability associated with stream size, changes in flow affect the measurement of width:depth. This source of variation must be considered when using width:depth as a monitoring parameter.

A method to account for temporal variation in discharge

To compensate for the effects of varying flow, discharge should be "standardized" for sampling sessions. This is done during the initial low-flow/base-flow sampling session by setting up a permanent staff gauge near the monitoring site, in a location where the channel and bank are not likely to change (eg, a bridge, bedrock outcrop, etc...) and noting the water level on the gauge and measuring the corresponding discharge (using a flowmeter). This then becomes the "standardized discharge" ($Q_{standard}$). Monitoring should then be conducted during periods when flow approximates the same height on the staff gauge (height should be recorded on the data sheet). The relationship between staff gauge height and discharge allows the observer to visually and quickly determine if the stream is at a level suitable for width:depth monitoring. To verify that similar flow conditions exist, additional discharge measurements should be made periodically; it is recommended that at least 1 flowmeter measurement be made prior to each sampling session.

Spatial variation and how it affects width:depth monitoring

Both width and depth vary spatially within the channel and between different types of channel units. Channel width varies in response to a whole host of factors, including valley form, channel constraint, sediment and water flow, adjacent bank slopes, and riparian vegetation. A constrained channel with banks confined by bedrock (A-type; Rosgen, 1985) yields a different width:depth than a channel flowing through a low-gradient, broad floodplain reach (C type). If width and depth were collected at a deep pool, for example, the ratio would be different than if it were taken at a wide and shallow riffle. The measurement of width:depth must take into account this source of spatial variation for it to be useful as a monitoring parameter.

Land use effects on width:depth vary in response channel and valley morphology. Changes are more easily detected in low-gradient, unconstrained (C-type) reaches. Comparing width:depth ratios between different reach types may serve only to illustrate differences due to natural physical factors and not land management effects.

Selecting monitoring sites to minimize spatial variation

The location for measuring width:depth should be standardized to minimize sampling bias errors. All width:depth assessments should be taken in pools and where the maximum depth occurs (K. Overton and B. House, personal communication). Pools are easily-located and maximum depth is one of the dimensional variables which can be determined with minimal observer bias.

The thalweg of the pool should be located and point where the maximum pool depth occurs should be identified. The maximum depth should be measured with a graduated rod. The wetted width of the channel should also be measured at the location of the maximum depth. These two values are then used to derive the wetted width: maximum depth ratio for each sampled pool. The frequency of sampling at pools should correspond to those used in deep pool frequency sampling (ie, measurement at every pool).

Stratification of stream reaches based on channel morphology should be used to minimize spatial variation due to reach differences. A preliminary basin-wide stream survey should be conducted to locate unconstrained, low-gradient reaches (C-type) in each monitoring watershed. All low-gradient C-type reaches should be selected as monitoring sites. For monitoring width:depth, low-gradient is defined as average stream channel gradient of 1% or less (see Platts et al 1987 for measurement methods). Sampling should occur at a standardized discharge (refer to previous discussion of $Q_{standard}$).

The wetted channel width : maximum pool depth measurements collected in each sampling reach should be pooled to calculate a mean ratio for each reach (along with standard deviation, error, and variance).

To minimize observer bias in locating pool sampling sites, crews should conduct pre-survey exercises in which teams can examine of variety of pool types and collectively agree upon the precise location to collect depth:width. This should be recorded in the data sheets or summary report and photographs should be provided as supporting documentation.

Monitoring land management effects on width-to-depth ratios: direct or indirect/cumulative effects?

The width:depth ratio is influenced by input of sediment and water to the channel and is sensitive to land management activities that alter these processes. Changes in width:depth due to localized direct effects may be useful for monitoring livestock grazing impacts. However, for timber harvest or roading, it may be difficult to separate local effects from off-site or cumulative land use effects dispersed throughout the watershed, since the channel serves as a routing conduit to mix both natural and management effects. Consequently, cumulative width-to-depth monitoring may be appropriate for assessing harvest/roading impacts to streams.

Monitoring study design and data analysis to assess local direct effects of grazing on width:depth ratios

Upstream "control" above allotments and downstream "treatment" within allotments can be set up as monitoring sites. A minimum of 10 width:depth measurements should be taken at each site. To minimize the influence of longitudinal spatial changes due to increases in stream order etc..., the sites selected should be in relative close proximity and within a homogenous reach, without separation by additional tributaries or changing landforms. If requirements for parametric analysis are met (eg, test normality, variance homogeneity, etc...), the differences between the paired mean values can be tested for significance using a 1-tailed t-test (Ponce, 1980; Devore and Peck, 1984).

Monitoring study designs and statistical analyses to assess indirect/cumulative land management effects on width:depth ratios

The data collected from the control watersheds should be used to develop a "natural" range of variability in width:depth ratios. This can take the form of a statistically-derived confidence interval (calculated from the mean frequency and standard error) or a "tolerance range" (D. Turner, USFS INT, personal communication). This range serves as a basis for analysis and interpretation of the monitoring data.

For the width:depth ratios, the sampling unit is the reach. Since width:depth was sampled at all pools in all low-gradient reaches, the total population is included in the sample size. Normal distribution and homogeneity of variances should be checked before attempting to use parametric statistics (distribution graphing, chi-square goodness of fit, Kolmogorov-Smirnov, or Shapiro-Wilk tests for normality tests; Bartlett's test for variance homogeneity; refer to Ponce 1980, Devore and Peck, 1986). Data can be transformed if not normally-distributed (typically, a log-normal transformation is appropriate; P. Flebbe, USFS SEFES, personal communication). Non-parametric methods are an alternative if assumptions for parametric analysis are not met.

Using an established "natural" range and grouped watersheds

Assuming that requirements for parametric tests are met, the data from treatment watersheds should be compared to the calculated "natural" range (confidence interval or tolerance range) determined from the group control; if outside the range, this would suggest that indirect/cumulative land uses may be having an effect on pool frequencies. A t-test can be used to determine if the differences are significant (t-test appropriate for treatment versus control type study, to compare 2 populations when variance is unknown and data are paired or unpaired). The selection of a one-tailed or two-tailed test depends on the null hypothesis (may be appropriate to use 1-tailed since we are interested in determining if the mean is less than the critical t-value). The method for the t-test is described in Ponce (1980).

Non-parametric statistical tests such as Wilcoxen, Mann-Whitney, or Kruskal-Wallace may be used if parametric assumptions are not met (P. Flebbe, personal communication).

Interpretations should be supported by other quantitative data including the % of basin which is roaded or harvested; sediment yield quantity (by sediment modelling, sediment budget analysis. V* [Lisle 1991], etc...), GIS analysis of activity/source sites; yearly channel mapping; and photographs taken at established locations; and other types of supporting evidence which document that management has occurred and has generated some effect on LWD frequencies should be provided as support for this analysis (P. Flebbe, personal communication). (Refer to Appendix A for description of photo point methodology.)

Cumulative width:depth monitoring analysis without control watershed group data

If a control group is not used, the background range of variability cannot be assessed. The data collected from the managed watersheds should therefore be compared to the width:depth ratio of 10 as given in the DFC descriptions. Analysis should be limited to qualitative interpretation and supported by other data, such as that described above. It is not recommended that statistical assessments be made on this type of data.

HABITAT ELEMENT: WATER QUALITY -- STREAM WATER TEMPERATURE

DESIRED FUTURE CONDITION

Stream water temperature regimes are well-moderated with limited day to night variation. The range of summer temperature variation, maximum temperatures, and duration of temperature elevation in forest/rangeland streams are well within the metabolic tolerances of aquatic organisms historically found in the system.

Data collected from streams in the upper Columbia River Basin and information from the scientific literature suggest that this range should not exceed an average of 68 degrees Fahrenheit during the warmest months of July and August.

STREAM TEMPERATURE MONITORING OBJECTIVE

Monitor the effects of land management activities on stream water temperature. Determine if standards and guidelines or best management practices employed in grazing and timber harvest/roading activities are effective in maintaining or decreasing the range of temperature variation below **68 degrees F (July-August two-month average daily maximum temperature)** in upper Columbia River basin streams. This objective incorporates both a maximum value and duration assessment which is important for addressing stream temperature effects on salmonids.

JUSTIFICATION FOR MONITORING WATER TEMPERATURE

Biological importance

Water temperature is one of the most important variables affecting salmonids and other stream biota (Fry, 1947, 1964; Hutchinson, 1976; Armour, 1988; Keeton, 1967). Temperature influences timing of migration and spawning, egg maturation, growth, incubation success, intra- and interspecific competitive ability, and resistance to parasites, diseases, and pollutants (Bjornn and Reiser, 1991; Reeves et al 1987). Increased temperatures have been related to reductions in salmonid abundance or changes in their spatial distribution (Platts and Nelson, 1988; Marcus et al 1990; Hynes, 1970).

Tolerances vary by life stage and species. Sustained temperatures above 73 to 79 degrees F (23 to 26 degrees C) are lethal for salmonids; optimal growth occurs from 50 to 61 degrees F (10 to 16 d C) (Brett, 1952; Bjornn, 1978). The duration of temperature elevation and the pre-elevation acclimating temperature are important factors that affects salmonid metabolic response to increased water temperatures (Lantz, 1970).

Most information on water temperature/salmonid tolerance has been collected from laboratory experiments. In streams, however, salmonids have behavioral adaptations that allow them to survive brief exposure to lethal temperatures; fish respond by avoiding such areas and move to seek out cool water refuges (eg, groundwater seeps, mouths of tributaries) (Brett, 1952; Gibson 1966; Kaya et al 1977). The wide thermal tolerances of stream salmonids and natural diurnal cycling of water temperatures enables them to survive such thermal fluctuations (Beschta et al 1987). Little data is available which documents the duration of temperature elevation that can be withstood by salmonids under spatially and temporally-heterogenous stream conditions.

Physical importance

Stream temperature is an easily-measured water quality variable that has considerable chemical/physical significance (Wetzel, 1983). Stream temperatures reflect both the seasonal change in net radiation and daily changes in air temperature (Brown, 1969). Temperature is one of the most important factors affecting chemical reactions/rates and hydraulic properties in streams. Known relationships exist between dissolved oxygen and temperature, and dissolved oxygen is one of the important chemical parameters influencing the abundance and distribution of aquatic biota (Schmidt-Nielsen, 1985).

Relationship to land management activities

Stream temperature has been used to assess both site-specific, direct effects, and basin-wide cumulative effects resulting from land management activities. Loss of riparian vegetation and streamside shading through grazing, timber harvest, and roading can have direct effects on stream water temperature, with the magnitude of temperature increase is proportional to the reduction of shade (eg, Brown, 1970; also see Beschta et al 1987 for a review). Management activities can also indirectly increase temperature by reducing riparian vegetation cover through sediment loading/aggradation and resulting channel instability and bank erosion. Holtby (1988) studied the effects of logging on stream temperatures in Carnation Creek, British Columbia, and noted that temperature increases altered timing of seaward migration for coho salmon smolts, which may have resulted in decreased smolt survival and lower adult returns.

METHODS TO MONITOR STREAM WATER TEMPERATURE

The monitoring data of interest in this objective is the **July-August two-month maximum average daily water temperature**.

Temporal variability in stream temperature and how it affects its monitoring

Hourly, daily, and seasonal fluctuations in stream water temperatures occur in response to diurnal cycles, changes in climate, variations in solar paths, etc... The period of time in which high temperatures occur as well as the actual temperature measurement itself should be ascertained to assess impacts to salmonids. Methods to monitor land use effects on stream temperature must be able to identify both a discrete point (*maximum temperature*) and the *duration* of such effects amidst high levels of temporal variability.

Sampling devices and methods to determine temporal variability in maximum temperature, and to measure its duration

Determining the hourly, daily, weekly, and monthly range of variability in water temperature, the maximum level of increase, and the duration of such levels requires continuous and systematic sampling. There are several methods to collect maximum temperature and range information. Hand-held thermometers can be used if frequent visits to the stream are made. However, these methods require that such sampling takes place within a narrow window corresponding to when the highest daily temperature occurs; this may be logistically unfeasible if monitoring sites are remotely located. Periodic visits (daily) are also needed to determine the duration of elevated temperatures, also increasing the amount of time, effort, and associated costs needed for data collection.

Maximum/minimum recording thermometers can be used to record the highest stream temperature that occurs during the sampling period. However, the duration cannot be assessed unless frequent visits to the site are made at regular intervals. As with hand-held instruments, using max/min thermometers to collect both maximum temperature and duration data may impose excessive demands on time and personnel resources.

An alternative method is to utilize devices such as recording thermographs. Thermographs can be set to sample at periodic intervals which correspond to known temporal fluctuations. Once installed, both the highest stream temperature and duration in which it occurs can be automatically sampled without additional site visits during the entire sampling period. Their ability to link with PC computers aids in data retrieval. Recent technological advancements have lowered the price of such devices and they should be considered as an efficient and cost-effective tool to monitor stream water temperatures.

If thermographs are used, they should be programmed to record temperature at hourly intervals for the entire sampling period. These devices must be calibrated before installation (using ice water, etc...). The devices should be recovered no later than the onset of high flows in the fall.

Duration is addressed by using the two-month average maximum temperature collected from July to August, rather than the single maximum temperature measurement. This is determined by calculating the mean daily maximum temperature during this 62-day period. These calculations should be performed on data from every selected sampling site and for each sampling period. Although the 2-month period is not based on high temperature duration tolerances established from field research (little such data is available), it has been commonly-used as a measure for assessing stream temperature/salmonid fish relationships in the Northwest (eg, Hostetler, 1991).

The influence of climatic variability on stream temperature monitoring

Monitoring must distinguish between natural variation and the effects of human activities. However, since temperature is highly influenced by climatic variables, a "pre-activity" background data set must be extensive; a statistically-valid sample size for these type of data is 30 years or more (P. Flebbe). This places restrictions on the study design and the type of comparisons that can be made; the design must either compare control or treatment watersheds, or upstream/downstream sites around the activity.

Spatial variability in stream temperature and how this affects its monitoring

Temperature varies within the water column, along the latitudinal axis of the stream, and between different geomorphic channel units. This must be considered when selecting specific locations to collect stream temperature monitoring data.

Variation occurs laterally between different channel types in the stream and vertically within the water column. Pools exhibit thermal stratification, with potential temperature gradients as high as 9 degrees F (5 degrees C) from surface to bottom (Bilby, 1984). Variation also occurs respective to location in the channel. Warming or cooling can occur along stream margins, especially in slow-moving stream sections. Smaller streams with less flow exhibit greater daily fluctuations in temperature than larger streams with greater water mass (Meehan, 1970; Bjornn, 1978: Meehan, 1991). This affects the selection of sampling sites to monitor land use effects on water temperature.

Stream temperature variations occurs between sections of a watershed due to factors such as input of groundwater; mixing of tributaries; increasing distance from input sources; abundance, density, or distribution of riparian vegetation shade; valley floor morphology; and hillslope topography. When attempting to separate these factors from land management

effects, such sources of variability can be difficult to account for and may confound interpretations of monitoring data. These influences are particularly relevant to monitoring the effects of cumulative, basin-wide temperature effects.

A sampling method to account for spatial variability in stream temperature

Temperature data should be obtained only from mid-channel areas of units with adequate turbulence and mixing (such as a riffles or cascades), towards the center of the channel. If a thermograph is used, the sensor probe or entire unit should be completely submerged, concealed, and weighted to prevent dislodgement. The sensor should not be placed in contact with the stream bottom. (A stainless steel or plastic holding bracket mounted permanently to the stream bed with waterproof epoxy makes a reliable anchoring system.)

Monitoring land management effects on stream temperature: direct or indirect/cumulative effects?

Water temperature is a sensitive indicator of land use impacts on stream resources and is easily quantified. If effects are localized (eg, a timber harvest unit along a stream, a heavily-grazed streamside pasture), direct temperature effects can be effectively monitored. Indirect or cumulative impacts on stream temperature are more difficult to assess because at the basin scale, multiple sources of water inputs, changes in reach morphology, etc... can result in variability in the longitudinal temperature profile and may mask land use effects. To assess such variability, cumulative temperature monitoring may involve numerous sampling sites; for Steamboat Creek (Oregon), Brown et al (1971) used up to 17 thermographs. The logistics and costs of setting up a cumulative effects study may be prohibitive for agency field units. Stream temperature may therefore be more appropriate for monitoring direct land use effects.

Study designs and data analysis for evaluating direct effects of a single activity

The upstream "control" site and downstream "treatment" adjacent to the harvest, roading, or grazing activity are used to assess direct land use effects (example study design in Brown et al 1971). If data meet assumptions for parametric testing, differences in the 2-month mean maximum between control and treatment sites can be tested using a one-tail t-test (because we are interested in determining if treatment temperatures are higher than the control) or comparison to statistically-derived "tolerance intervals" (D. Turner, USFS INT, personal communication).

Normality and other parametric assumptions should be tested (distribution graphing, chi-square goodness of fit, Kolmogorov-Smirnov, or Shapiro-Wilk tests for normality tests; Bartlett's test for variance homogeneity; refer to Ponce 1980, or Devore and Peck, 1986).

Data can be transformed if not normally-distributed (typically, a log-normal transformation is appropriate; P. Flebbe, USFS SEFES, personal communication). Non-parametric methods are an alternative if assumptions for parametric analysis are not met.

For the final step of the analysis, the July-August maximum average temperature from the managed watersheds should be compared against the 68 degree F threshold value for this DFC element. Other supporting documentation should be provided as well. Photographs, riparian management prescriptions, riparian surveys, etc... would help to substantiate the interpretation of the monitoring data.

Length of sampling for direct temperature effects monitoring

If the goal is to assess whether or not a land use activity is having an effect on stream temperature, or if an S&G for protecting shade canopy is effective in maintaining shade density and water temperatures, monitoring may need to be conducted only during the summer period following the completion of the activity. However, if objectives are to assess effectiveness of protection measures designed to promote temperature recovery, longer studies may be needed. The duration of water temperature monitoring should be determined by factors such as geographic locality/climate, and time necessary for riparian vegetation recovery of shade canopies. Research suggest that recovery times may be in terms of decades (reviews in Beschta et al, 1987). Temperature recovery time can be modelled using mathematical programs such as Brown's equation (Brown, 1970) or SHADOW (Park, 1991). Results can provide additional guidance on the appropriate length of such monitoring to assess temperature recovery.

HABITAT ELEMENT: STREAMBANK STABILITY AND BANK ANGLE

DESIRED FUTURE CONDITION

Streambanks which border channels in low-gradient, wide valley floor sections (C-type channels; Rosgen 1985) are stable and exhibit little sign of active erosion. The angle of the lower bank section is vertical or concave to promote the formation of important undercut bank cover habitat for fish and other aquatic organisms.

No upper Columbia River basin threshold values have been derived for these objectives. However, the criteria for an undercut bank is one where the angle is less than 90 degrees (Platts et al 1987). This may be useful as an interim threshold value for comparison, although House (personal communication) has documented that even in "pristine" C-type Alaskan streams, not all banks displayed undercut characteristics.

BANK STABILITY AND BANK ANGLE MONITORING OBJECTIVE

Monitor the effects of land management activities on **percent of stable bank** and **maximum lower bank angle**. Determine if standards and guidelines and/or best management practices employed during grazing activities are effective in maintaining or increasing bank stability and bank angle characteristics in low-gradient, unconstrained C-type channels in upper Columbia River basin streams.

JUSTIFICATION FOR MONITORING STREAMBANK STABILITY AND BANK ANGLE

Physical importance

The bank material of natural streams influences channel pattern and form and provides a boundary between aquatic and terrestrial realms. The resistance or erodibility of banks influences channel meandering, and bank erosion is one of the principal means of sediment supply to streams (Knighton 1987). Bank stability and angle provide an indication of channel integrity. Bank erosional processes include slumping, hydraulic shearing, rotational action, and frost expansion (Knighton 1987).

Biological importance

Well-vegetated, stable, and non-eroding streambanks develop undercut bank habitat which is utilized as cover by various life stages and species of salmonids. In low-gradient, meandering stream channel, the amount of undercut bank habitat has been correlated with fish abundance and diversity. Stable banks are linked with channel stability and the maintenance of complex, diverse aquatic habitat for stream biota (Platts et al 1987).

Relationship to land management activities

Livestock grazing alongside streams can be one of the major impactors to banks and associated riparian vegetation (see review by Kauffman and Krueger, 1984). Foraging and trampling by livestock animals can cause direct mechanical shearing and slumping of the bank; remove riparian vegetation, resulting in loss of soil retention by plant roots and increase bank erodibility; expose soil to surface erosional processes; and cause compaction that reduces soil porosity and increases surface water retention and overland flow. Actively slumping banks in grazing allotments are an obvious indicator of overuse by livestock, and bank stability and bank angle have been used as monitoring parameters to assess such effects (Platts et al 1987).

Other land uses which result in de-stabilizing the integrity of stream channels and affect bank erosion rates and angles include increased sediment and water delivery to streams channels as a result of upslope timber harvest, associated roading activities, and mining (Meehan, 1991; Martin and Platts, 1981). Clearcut logging was associated with the collapse of streambanks, loss of winter refuge habitat and re-distribution of coho salmon in Carnation Creek, British Columbia (Tschaplinki and Hartman, 1983).

METHODS FOR DETERMINING STREAMBANK STABILITY AND BANK ANGLE

Spatial variability in bank characteristics and how it affects their measurement and monitoring

Spatially-variable factors such as stream and valley morphology, channel and upslope processes, riparian vegetation, soil type, and underlying geology can affect streambank characteristics. Comparing bank features between various sections of streams may only serve to illustrate intrinsic reach differences and not the effects of land management activities. This variability affects the use of streambank angle and stability as monitoring parameters.

Certain types of reaches and channel locations are more susceptible to bank erosion. Areas along the outside of meanders are subject to greater hydraulic shearing forces and bank instability is more likely to occur at these sites. Banks in low-gradient, wide valley floor areas (C-type; Rosgen 1985) are typically composed of depositional material and are more erosion-prone than those in bedrock-lined gorges (A-type). Bank stability may a strong indicator of fish habitat condition in unconstrained, alluvial meandering channels (Overton personal communication; Platts et al 1987).

Bank angle is influenced by the type of material and its cohesive properties and the fluvial processes which create streambanks. An actively eroding bank comprised of fine sedimentary material may have a much different angle than one which is composed of resistant cobble and boulder particles. Angle in erosion-resistant, bedrock-controlled channels is extremely variable and relatively insensitive to land use impacts (Platts et al 1987). In contrast, angle may be a very useful parameter in alluvial channels found in unconstrained valley floor reaches. Undercut banks are typically more heterogenous than outward sloping banks and are often composed of a multitude of undercuts of varying shape and size (Platts et al 1987). Such sources of variability can make it difficult to both measure and interpret bank monitoring data.

Methods to account for spatial variability in bank stability/angle monitoring

Monitoring sites in a watershed should be stratified by reach type so that the effects of spatial variation can be reduced. Sampling of bank stability and angle should be conducted in low-gradient, unconstrained reaches (C-type channels; Rosgen, 1985). These sites are most sensitive to bank alteration from management activities and are especially appropriate for monitoring livestock effects, since they usually coincide with the location of grazing allotments in a watershed. Low-gradient reaches are best located by conducting a preliminary basin-wide stream survey.

Streams in C-type channels are typically meandering, and the outside meanders or adjacent point bars should be avoided as sampling sites. Measurements should be taken in areas where the channel is relatively straight to aid in distinguishing natural erosion from land use effects.

Statistical and observer bias in estimating bank erosion and angle

Streambanks are morphologically complex and such heterogeneity makes it difficult to measure the degree of stability and to derive a representative bank angle. The method employed for determining stability and angle must be able to reduce such sampling errors.

Visual estimates of bank erosion are subject to high observer bias. Traditionally, determination of bank stability and angle relied on categorization schemes such as "mostly unstable, mostly stable", "less than 25% unstable, 25-50% unstable, etc...", "angle greater or less than 50%", etc... Consistency between observers is difficult to maintain given the high variability of potential features that are used to classify "unstable" and "stable" banks (Platts et al 1987). Visual quantification of percent area and bank angle are also subject to error depending on the abilities of individual observers. The use of channel transects and visually-estimated percent stability categories was evaluated by Platts et al (1987); while precision was rated as fair-to-good, accuracy was evaluated as fair to poor. They also indicated that profiles cannot distinguish natural from artificial erosion, although they found that cross-section transects did reduce confidence intervals.

For banks which slope outward (i.e., which have bank angles greater than 90 degrees), bank angle is relatively easy to determine (Platts et al 1987). However, undercut banks with angles less than 90 degrees tend to be morphologically more complex and varied. Measuring the angle is further complicated because the points delineating the angle are difficult to locate. This results in higher variance for undercut versus out-sloping banks (Platts et al 1987).

Methods to account for statistical and observer bias

Prior to monitoring, crews should develop a consensus on what site-specific, local features are used to determine an unstable or stable section of streambank. Characteristic generally used to identify an unstable bank are active or recent sloughing, shear cracks, or exposed sandy/loamy soil (USDA Forest Service R5 survey methodology). Regardless of which criteria are used, written and photographic records should be kept so that consistency can be maintained between sampling periods and different observers.

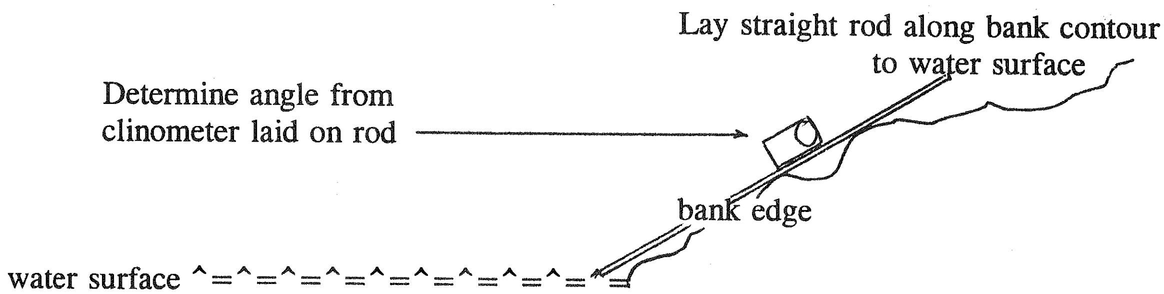
Bank stability can be quantified by using a modification of the cross-sectional transects (Platts et al 1987). Bank stability is determined by placing the ends of the transects up the sides of the bank and measurement of the total linear bank area under the transect line which is "unstable". The total linear area is used to quantify percent unstable (this is a modification of Platts et al because they used classifications instead to collect categorical data). A minimum of 10 transects should be randomly located along the bank (sample size suggested by P. Flebbe, personal communication).

Maximum bank angle should be measured by using methods described in Platts et al (1987). (See Figure 1 for explanatory diagrams.) For banks which are not undercut, a straight rod is placed along the top of the bank, with its end touching the surface of the water. A clinometer is laid on top of the rod to determine the angle. This measurement is then subtracted from 180 to obtain the actual lower bank angle. For a non-undercut bank, lower bank angle is always equal to or greater than 90 degrees. The maximum bank angle measurement should be taken at the location of the least bank slope in the sampling reach.

For a bank which is undercut, the straight rod is positioned so that it makes contact with the outermost extension of the bank. The rod is then pushed back to the farthest extension of the undercut, until it touches the water surface. A clinometer laid on top of the rod is used to measure the angle. For an undercut bank, the angle is always less than 90 degrees. If more than one undercut exists, maximum bank angle sampling should take place only at the dominant undercut where the greatest amount of undercut occurs (see Figure 1). At least 10 bank angle measurements should be taken in each monitoring reach (P. Flebbe, personal communication).

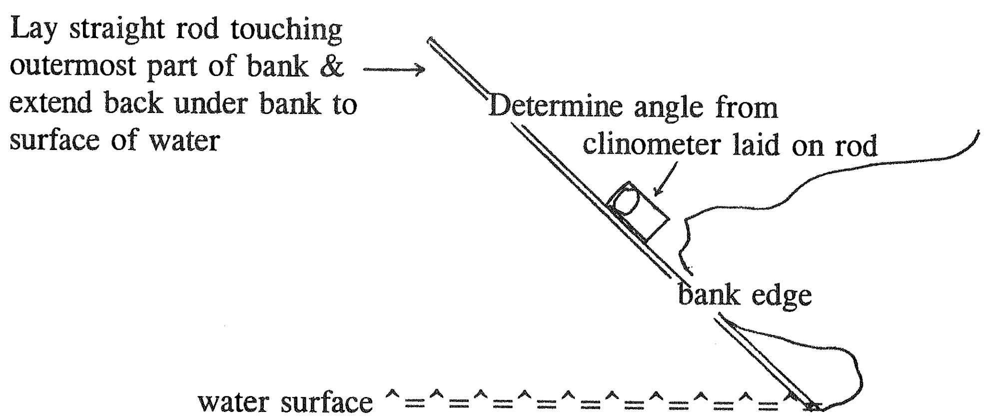
Figure 1. Measuring lower streambank angle (from Platts et al 1987).

A. *For banks which slope outward & are not undercut*: LOWER BANK ANGLE > = 90 degrees

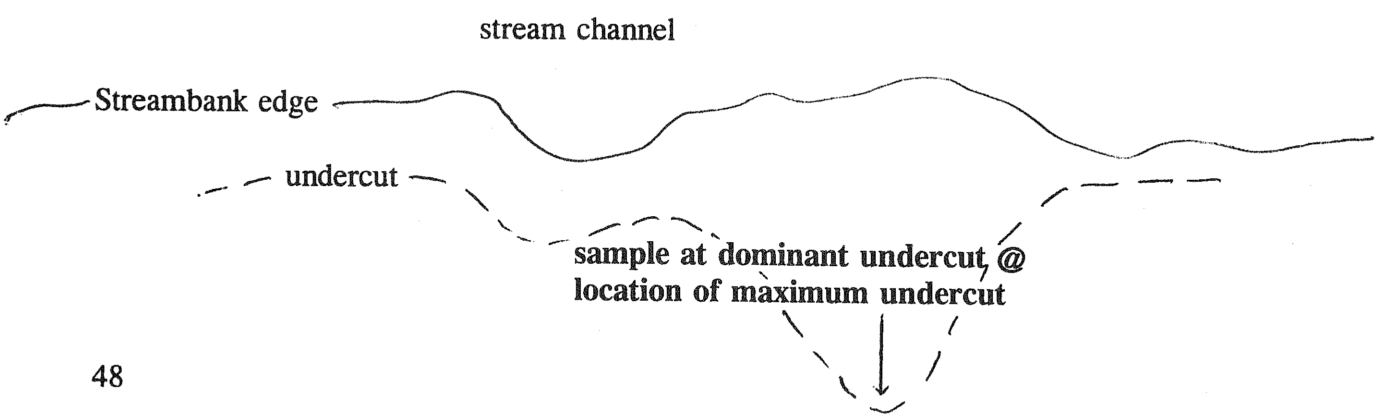


lower bank angle = 180 - (clinometer reading)

B. *For banks which are undercut:* LOWER BANK ANGLE < 90 degrees



Undercut bank angle sampling, plan (overhead) view:



Monitoring land management effects on bank stability and angle: direct or indirect/cumulative effects?

Streambank stability is influenced by a host of natural processes and land use activities. It may be impossible, however, to de-couple *timber harvest and roading effects* on bank stability from natural factors that cause streambank erosion. Bank angle and stability may not be useful as a monitoring parameter for these types of activities; other parameters which focus on channel morphology features (eg, pool frequency, etc...) may be more appropriate.

Bank stability and angle do provide useful measures of *grazing effects on streams within certain channel types*. Attempting to assess indirect or cumulative grazing activities which occur throughout a watershed, however, may be difficult, since at this scale, the influence of natural processes, variability, and other land uses make it difficult to separate impacts associated with livestock use.

Perhaps the most appropriate use of bank stability and bank angle parameters is for monitoring the *direct effects of livestock use* on streamside grazing allotments found in unconstrained, alluvial reaches (C-type channels; Rosgen, 1985). In this case, impacts are relatively localized and can be directly attributed to the activities of livestock. Since animal access can be controlled, their effects can be spatially isolated. This then allows the establishment of control and treatment sites for direct effects monitoring.

Monitoring study design and data analysis to assess direct effects of grazing on bank angle and stability

For monitoring livestock grazing effects on bank stability/bank angle, sampling should occur both within the allotment ("treatment") and at an adjacent site located upstream ("control"). Animals can be excluded from the control site with exclosures; however, the control site selected must not have been grazed in the past (otherwise this design will test the *effectiveness* of exclosures, not the *effects of exclusion*).

The paired sets of angle and stability measurements should be analyzed for normality and homogeneity of variance (distribution graphing, chi-square goodness of fit, Kolmogorov-Smirnov, or Shapiro-Wilk tests for normality tests; Bartlett's test for variance homogeneity; refer to Ponce 1980, Devore and Peck, 1986). Data can be transformed if not normally-distributed (typically, a log-normal transformation is appropriate; P. Flebbe personal communication). If parametric assumptions are satisfied, differences in the paired data means should be analyzed with a one-tail *t*-test. Non-parametric methods are an alternative if assumptions for parametric analysis are not met.

Length of sampling for monitoring grazing effects on bank stability and angle

During the monitoring study, sampling should continue regularly throughout the course of grazing on the allotment. Once animals are removed, sampling frequency and duration should correspond to rate of recovery of banks from grazing effects, as influenced by type of riparian vegetation, growth rates, intensity of grazing, etc... It is difficult to pinpoint a specific periodicity and duration for streambank stability/angle monitoring because of the influence of unpredictable variables (eg, weather and precipitation), the complex interactions between natural processes and land use effects, and our relative inability to accurately predict rates of recovery. Long-term studies of bank stability recovery following impacts by land uses indicate that time periods on the order of a decade or more may be involved (eg, Kauffman and Krueger, 1984).

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Copies of these articles can be obtained by mail from the USFS National Aquatic Monitoring Center, Dept. of Fisheries and Wildlife, Utah State University, Logan, UT 84322-5210 OR by DG: G.Chen:S22L06A, OR by FAX 801-797-1871, OR phone request 801-797-1090

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APPENDIX A

Techniques for Photo Points

a. Identify the stream reach and mark photo point reference with steel fence post, tagged trees, of other suitable, easily relocated marker. Describe relationship of reference point with actual photo point (i.e., 30 feet, 180 degrees from reference point.)

b. Use 35 mm camera equipped with a 28 mm focal length lenses (critical that photopoint always be photographed using same focal length lenses.)

c. Take one photo upstream from photo point, one photo downstream, and one photo across stream channel. Always take photos in same order (i.e., upstream, downstream, across stream.)

d. Include photoboards with photographer, date, stream name, segment identifier, and legal description (i.e., township, range, section, subdivision) in the first photo taken.

e. Include staff rod of similar device for estimating stream width and depth (showing deepest point in stream) in each photo.

APPENDIX B

Techniques For Riparian Vegetation Surveys

<u>200 Pace Toe Point Transect</u>

a. Identify stream reach and mark with steel fence post, tagged tree, or other suitable, easily relocated marker. Stream reaches selected should be those which can reasonably be expected to respond to a change in management.

b. Beginning at the outer edge of the riparian zone begin pacing on a line at an angle to the stream channel and in a general upstream direction. At each foot fall record the species and height of the tallest plant above you toe and dominant and co-dominant overstory and understory species.

c. Unless the stream is too large to easily wade, continue the transect until reaching the outer edge of the riparian zone on the opposite side of the stream from which the transect in begun. Then, continue back across the riparian zone in a zig-zag fashion until 200 records have been take. O streams too large to easily wade, record 100 records from on side and then cross stream and record and addition 100 records from opposite side. Both transects must be on directly opposite each other on the same stream reach.

<u>Interpretation</u>

Data interpretation includes a determination of vegetative species composition, shrub and tree canopy height and percent cover, dominant and co-dominant overstory and understory species, and canopy distribution and potential.

APPENDIX C

NATIONAL AQUATIC ECOSYSTEM MONITORING CENTER
(801) 797-1090 DG: S22L06A

USDA FOREST SERVICE, WASHINGTON OFFICE
Dept. of Fisheries & Wildlife,
Utah State University, Logan, UT 84322-5210

The USDA Forest Service National Aquatic Ecosystem Monitoring Center was established in 1992 to assist field unit resource specialists with their aquatic monitoring programs. Our main objectives include technology transfer, lab sample processing, consultation and on-site assistance, and continuing education in aquatic monitoring.

Gordon Haugen
Columbia River Basin Task Force Coordinator
USFS R6 Regional Office
Portland, Oregon

4. June 1994

Gordon:

Attached is version 6 of the Section 7 Upper CRB Monitoring Protocol.

The issue of how width:depth ratios are to be monitored is still hotly debated among those whom I have spoken with. As I mentioned in my April 19th letter, the suggested methods are quite disparate, ranging from measuring width to depth at max depth location of pools, to width to depth using bankfull width at riffles, glides, or runs. Each method has its merits and strong supporters. This version contains the method that was suggested by Bob House and Kerry Overton -- width:depth measured at max depth location of pools -- and agreed upon by the original work group. There will probably be a lot of continuing argument among resource specialists about this section. Nevertheless, we all recognize that a region-wide standard is needed so that the data can be compared at this scale, and for this reason, we would urge that units collect their width:depth data using these methods. Our suggestion to the field units who are implementing this procedure and who want to measure width:depth in another manner is to use BOTH methods, and compare the results for consistency, repeatability, and the ability to detect change. We would like to obtain the results from such comparisons and may use them to revise the width:depth section.

I have also recently fielded concerns about the absence of a protocol to assess intergravel fine sediments. John Sanchez from the Umatilla NF indicated to me that NMFS was requiring them to address the fine sediment issue on their Tucannon sales. It was a case of "monitor fine sediment or no activity" and so John, myself, and Pomeroy RD hydrologist Jim Thinnes developed a specific and separate protocol to actually monitor intergravel fines (Thinnes prepared the document while we provided advice and review). It looks quite good and I suggest that it can be included as an appendix to the Section 7 protocol for those Forests which have a specific need to monitor fine sediment. I am NOT suggesting that it be added to the Regional protocol as a required methodology because fine sediment problems may or

may not be an issue for each Forest. There are many problems associated with monitoring fines and the difficulty of doing it in a quantifiable and repeatable manner, the extremely high natural variably associated with fine sediment (and how to account for that in a statistically-valid sampling scheme), its analysis/interpretation, as well as trying to pinpoint the source from a myriad of many potential sources, provide strong arguments against monitoring fine sediment unless it has been determined to be an important land use effect AND a critical limiting factor to salmonids for a particular watershed. This should be evaluated on a case- by-case basis and not required as a whole for the CRB. We strongly urge any Forest who is proposing to embark on a fine sediment monitoring program to consider the needs and logistics before making the considerable resource commitments. We also suggest that units contact any member of the group or the Aquatic Monitoring Center to help them design a protocol that will be specific to their needs. There are too many examples where Forests have spent large amounts of money to collect fine sediment data that cannot be analyzed because no consideration was given to the effects of spatial, temporal, and observer variability and statistical requirements.

There have been several researchers who have developed methods to measure intergravel dissolved oxygen flow. This may provide us a more direct answer to the question of the actual effects of fine sediments on salmonids, rather than inferential techniques such as core sampling/sieving and use of generic fish survival relationships. These papers and a literature packet on fine sediments can be obtained from my office in Logan for those units who are interested (801-797-1090 or DG G.Chen:S22L06A).

I also fielded a phone call from Dale McCullough from Intertribe last week. Dale voiced strong criticisms of the document, in particular, the lack of a section on fine sediment monitoring. We spent quite a bit of time discussing the merits and problems of this but he held fast to need for everyone to monitor fines. He mentioned that Intertribe was working with a consultant to develop a fine sediment protocol and I suggested that he send me a copy so that we could share it among those that need to monitor fines. He also disliked the six DFC parameters that were selected by PACFISH and for this protocol and also had a number of editorial and substantive comments on the document. I asked him to send me a copy of his review. Hopefully, they can be included in a future revision of the protocol (as I have not yet received them). I asked Dale to send you a formal letter stating Intertribe's concerns.

Sincerely,

GLENN K. CHEN
Fisheries Ecologist
for the Upper Columbia River Section 7 Monitoring Protocol Work Group

Gordon Haugen
Columbia River Basin Task Force Coordinator
USFS R6 Regional Office
Portland, Oregon

19. April 1994

Gordon:

Attached is our 5th revision of the Section 7 Fish Habitat Monitoring Protocol for the Upper Columbia River Basin.

During the review period following the Boise meeting, we received only 2 sets of written comments. We decided to extend the time period beyond April 5th because several people called my office that day and indicated that they were sending comments. Many others indicated that they were providing reviews, but we have not received these to date. No additional comments have been received since 4/10 and we have therefore decided to complete this 5th revision based on the available input and your desired time line.

The issue of assessing width: depth ratios still remain. To provide some insight into the disparity of opinions, here is a sample of the proposed methods:

- W:D based on wetted width:max depth measured at pools @ location of maximum depth (used in this document)
- W:D measured according to Rosgen -- bankfull width compared to mean depth taken via 3 measurements at riffles
- W:D using bankfull width at runs or glides

The literature available to me shows variations in how channel width is measured, including wetted, bankfull, and active channel. Location of measurement also varied. The differences were related to the specific objectives that researchers were addressing (eg, determining channel geometry relationships, assessing change, etc...).

I am reluctant to alter the width:depth section without approval from the entire core team because members House and Overton expressed strong opinions about how this parameter should be measured. I suggest that we should convene a meeting (or phone conference) between the core members and some of the reviewers in order to resolve this issue.

You will note that, on the last page (Appendix C), we are attempting to develop guidelines and procedures for conducting the statistical analyses discussed in each protocol. We are envisioning the development of a simple, menu-driven PC-based program (using dBase or some other commonly-owned software available to most Forest Service units) that can be directly linked with the databases used to store monitoring information. We feel that this would greatly facilitate monitoring efforts for each unit and be extremely important for coordinating both PACFISH/Section 7 inventory and monitoring across the Columbia River Basin. The time frame for this project is uncertain, however, since decisions need to made as to which type of software to use, etc... We hope that the written methodology (not the computer portion) will be ready by October of this year.

Please contact me if you have any questions.

Sincerely,

GLENN K. CHEN
Fisheries Ecologist
National Aquatic Ecosystem Monitoring Center
801-797-1090
G.Chen:S22L06A

Gordon Haugen
Columbia River Basin Task Force Coordinator
USFS R6 Regional Office
Portland, Oregon

February 10, 1994

Gordon:

Attached is our 4th revision of the Section 7 Upper Columbia River Basin monitoring protocol. This document was reviewed by the core team and by a group of Forest Service and BLM fisheries biologists, researchers, and hydrologists. Their comments are incorporated into this draft. Names of core members and reviewers are listed on pages 1 and 2 of the document.

An issue that is still unresolved among the reviewers and core members is the measurement of width:depth ratios. The document uses definitions provided by Bob House and Kerry Overton (wetted width:max pool depth). However, others have suggested using bankfull width:depth measured at glides or runs. Depending on the outcome of further peer review, this portion of the document may change.

All reference material listed in the literature section is available from my office in Logan and can be requested at any time.

Please call if you have any questions.

GLENN K. CHEN
Fisheries Ecologist
Nat'l Aquatic Monitoring Center